Assessment of Surgical Performance

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ABSTRACT: Surgical patient outcomes are related to technical and non-technical skills of the surgeon. Trauma patient operative and management experience has declined since trainee duty-hour restrictions were mandated in 2003 resulting in less experience in technical surgical skills. The Advanced Surgical Skills for Exposure in Trauma (ASSET) cadaver-based course, teaching vascular exposure and haemorrhage control, was developed to fill this training gap. The aim of this Thesis is to develop surgeon performance metrics and to test surgeons before and after taking the ASSET course to determine whether such training improves performance of peripheral vascular control. The importance of training in surgical vascular control in both civilian and military practice, and a description of current surgical training for trauma are described in Chapter 1. Reviews of existing trauma training courses and surgical performance metrics are provided in Chapters 2 and 3, and show limited testing of training courses and lack of trauma surgical performance metrics. Data collection methods, evaluator training and analysis are described in Chapter 4. Chapter 5 evaluates self-confidence of surgeons performing the vascular control procedures in cadavers compared to the performance evaluated by trained evaluators. Preliminary validation of vascular-control performance metrics and testing of a standardized script with item analysis and inter-rater reliability are discussed in Chapter 6. Testing 40 surgeons performing 3 extremity vascular control procedures before and after training is reported in Chapter 7. ASSET training improves performance, but large performance variability, repeated errors and no improvements were found in some surgeons. Chapter 8 reports how blind video analysis checklist, global rating metrics, error occurrence and recovery show convergent validity with co-located evaluators. Chapter 9 identifies the key findings and implications, innovation of the work described in the Thesis and concludes with the potential impact on military readiness and my personal reflection on what I learnt.

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Thesis Supervisors: Nick Sevdalis, Professor of Implementation Science and Patient Safety, Department of Health Service & Population Research, King's College , London; Professor Charles Vincent, Emeritus Professor of Clinical Safety Science and Professor of Psychology, Department of Psychology, Oxford University.

RASP Colleagues and Evaluators: *Evan Garofalo, Stacy Shackelford, Kristy Pugh, Valerie Shalin, Hegang Chen, George Hagegeorge, Mayur Narayan, Elliot Jessie, Jason Pasley, Sharon Henry, Mark Bowyer, Babak Sarani, Niki Squires, Amechi Anazodo, Brandon Bonds, Nyaradzo Longinaker, William Teeter, Ann Romagnoli , Megan Holmes Alexys Monoson, Sam Tisherman, Adam Puche , Joseph Pielago.*

Surgeon Colleagues with whom I have worked: For over 35 years (1970- 2005) I was clinically active in Anaesthesia. I probably have administered well over 20,000 anaesthetics in my career, with increasingly sophisticated equipment and monitoring throughout these years. One common factor that was little changed in the 35 years during administration of these anaesthetics, were the technical skills for open surgical procedures demonstrated by the operating surgeon. I estimate that while working in 6 different countries over these 35 years I have seen over 6,000 different surgeons operate. My clinical anaesthesia practice included periods in General Surgery, Ear Nose Throat, Thoracic Surgery, Cardiac and Major Vascular surgery, Oncological surgery, Paediatric Surgery, Obstetrics and Gynaecology, Orthopaedic Surgery and a several-year period of experience in Trauma Anaesthesia, trauma patient resuscitation and Critical Care Medicine. As a result, I have been exposed to expert surgeons and those in training performing a variety of surgeries at different levels of urgency.

Family: Including my father Lewis Mackenzie, a Family Practice Physician who always encouraged me to "do an MD" and my brother Iain L Mackenzie who completed an MD at Cambridge University in 1969 winning both the Sir Lionel Whitby (Haematology) and Raymond Horton-Smith (All Cambridge Theses) Gold Medals for his Thesis. My thanks are especially due to my wife Cristina Imle and children Amelia and Lewis as well my colleagues with whom I have been associated during my over 40 years working at and around the University of Maryland Shock Trauma Center, Baltimore Maryland

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DECLARATION

I declare that I am the sole author of Thesis and that all work within this is my own, except where it is referenced or carried out in collaboration with others who are appropriately credited.

Signed:

Colin F Mackenzie

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Date: March 2nd 2017

Thesis output:

Papers Published and In Press:

1) Mark W Bowyer, Stacy A Shackelford, Evan Garofalo, Kristy Pugh, **Colin F Mackenzie**: *Perception Does Not Equal Reality for Resident Vascular Trauma Skills.* J Surg Res. 2015 Oct;198 (2): 280-8.
2) Stacy Shackelford, Evan Garofalo, Valerie Shalin, Kristy Pugh, Hegang Chen, Jason Pasley, Babak Sarani, Sharon Henry, Mark Bowyer, **Colin F Mackenzie:** *Development and Validation of Trauma Surgical Skills Metrics : Preliminary assessment of Performance after Training***.** J Trauma Acute Care Surg. 2015;79(1):105-110.
3) **Colin F Mackenzie,** Evan Garofalo, Stacy Shackelford, Valerie Shalin, Kristy Pugh, Hegang Chen, Adam Puche, Jason Pasley, Babak Sarani, Sharon Henry, Mark Bowyer. *Using an Individual Procedure Score before and after the advanced surgical skills exposure for trauma course training to benchmark a haemorrhage-control performance metric.* J Surg Educ. 2015; 72 (6) : 1278-1289
4) **Colin F Mackenzie,** Darcy Watts, Rajan Patel, Shiming Yang, George Hagegeorge, Evan Garofalo, Peter F Hu, Adam Puche, Valerie Shalin, Kristy Pugh, Guinevere Granite, Lynn G Stansbury, Stacy Shackelford, Samuel Tisherman: *Computer-assisted video hand-motion analysis of surgeon technical performance: a preliminary report of methodology and analyses.* Human Factors & Ergonomic Society Proceedings September 22nd 2016 pp 691-695
5) **Colin F Mackenzie**, Evan Garofalo, Adam Puche, Hegang Chen, Kristy Pugh, Stacy Shackelford, Samuel Tisherman, Sharon Henry, Mark Bowyer and the RASP Investigators*: Performance of vascular exposure and fasciotomy among surgical residents before and after training compared with experts.* JAMA Surgery Published Online March 1st 2017
6) **Colin F Mackenzie**, Jason Pasley, Evan Garofalo, Stacy Shackelford MD, Hegang Chen, Nyaradzo Longinaker, Guinevere Granite, Kristy Pugh, George Hagegeorge, Samuel A. Tisherman. *Head-camera video recordings of open trauma core competency procedures can evaluate surgical resident's technical performance.* J Trauma Acute Care Surg. Accepted In Press

7) Guinevere Granite, Kristy Pugh, Hegang Chen , Nyaradzo Longinaker, Evan Garofalo, Stacy Shackelford, Valerie Shalin, Adam Puche, Jason Pasley, Babak Sarani, Sharon Henry, Mark Bowyer, **Colin Mackenzie,** and RASP Group Investigators. *General longitudinal misperception of surgeons' surgical anatomic knowledge and vascular trauma skills.* Military Medicine Accepted In Press

Papers required in 2016 after acceptance at American College of Surgeons 2016 Clinical Congress

1) **Colin F Mackenzie,** Mark Bowyer, Sharon Henry, Samuel Tisherman, Hegang Chen, Nyaradzo Longinaker, Adam Puche, Kristy Pugh, Evan Garofalo, Aleys Monosoon, Stacy Shackelford**:** *Do Core Competency Trauma Surgical Procedural Skills Degrade with Time since Training?* J Am Coll Surg
2) **Colin F Mackenzie,** Darcy Watts, Rajan Patel, Shiming Yang, Evan Garofalo, Adam Puche, Kristy Pugh, Guinievere Granite, Valerie Shalin, Samuel Tisherman: *Sensor-free Computer Vision Hand-Motion Entropy and Video Analysis of Technical Performance During Open Surgery: Proof of Concept for Methodology.* J Am Coll Surg
3) Guinievere Granite, Kristy Pugh, Hegang Chen, Sharon Henry, Samuel Tisherman, Stacy Shackelford, Babak Sarani, **Colin F Mackenzie:** *Can Surgeons Making Repeated and Persistent Trauma Surgical Skills Errors be Predicted?* J Am Coll Surg

Abstracts:

1) **The assets of ASSET: surgical performance confidence through an anatomy and skills review course for surgeons**
   Evan Garofalo, Stacy Shackelford, Megan Holmes, Colin Mackenzie, Mark Bowyer. American Association of Anatomists Federation of American Societies for Experimental Biology (FASEB) academic meeting April 2014
2) **Mobile Platform to Evaluate Individual Surgeon Technical Skills**

Colin F Mackenzie, Mark Fitzgerald, Kon Mouzakis, Joost Funke Kupper, George Hagegeorge, Peter Hu, Evan Garofalo, Mark Bowyer, Sharon Henry, Stacy Shackelford Military Health Services Research Symposium Aug. 2015 Ft Lauderdale FL

3) **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) Military Health Services Research Symposium Aug 2015 Ft Lauderdale FL
4) **Evaluation of Surgeon Technical Skills before and After training.**
   Colin Mackenzie lecture: Trauma and Emergency Care Research Seminar Series Oct 15th 2014, University of Maryland School of Medicine
5) **Assessment of surgical anatomy skills in upper and lower limb vascular control and before and after training**
   Evan Garofalo, Stacy Shackelford, Valerie Shalin, Kristy Pugh, Hegang Chen, Jason Pasley, Babak Sarani, Sharon Henry, Mark Bowyer, Colin Mackenzie (Presenter) Assoc for Surgical Education Abstract Podium Presentation
6) **Mobile Platform for Assessing Emergency Trauma Surgical Skill Performance.**

   Colin Mackenzie, Stacy Shackelford, Evan Garofalo, Hegang Chen, Jason Pasley, Sharon Henry, George Hagegeorge, Kristy Pugh, Mark Bowyer. Assoc for Surgical Education Abstract Poster
7) **Surface anatomy in the performance of a lower extremity fasciotomy before and after training**
   Evan Garofalo, Stacy Shackelford, Valerie Shalin, Kristy Pugh, Hegang Chen, Jason Pasley, Babak Sarani, Sharon Henry, Mark Bowyer, Colin Mackenzie Federation of American Societies for Experimental Biology (FASEB) 2015
8) **Are Physical Models Comparable to Cadaver for Assessing Combat Surgical Technique?**
   Brandon W. Bonds, Evan M. Garofalo , Kristy Pugh, Nicholas Roney, Anish Gonchigar, Mark Bowyer, Stacy Shackelford, Colin F. Mackenzie Military Health Services Research Symposium Podium Presentation Aug 2015

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

10) **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. Military Health Services Research Symposium Podium Presentation Aug 2015

11) **Accurate Assessment of Surgical Skill Improvements after Training:**
Development and Validation of Trauma Surgical Skills Metrics, Preliminary Assessment.
Stacy Shackelford, Evan Garofalo, Valerie Shalin, Kristy Pugh, Hegang Chen, George Hagegeorge, Jason Pasley, Sharon Henry, Mark Bowyer, Colin Mackenzie. Military Health Services Research Symposium Podium Presentation Aug 2015

12) **Can hyper-realistic physical models of peripheral vessel exposure and fasciotomy replace cadavers for performance assessment?**
Jeremy Holzmacher, Babak Sarani, Adam Puche, Guievere Granite, Valerie Shalin, Kristy Pugh, Samuel Tisherman, Stacy Shackelford, Colin Mackenzie. Accepted as a Poster presentation to Am Coll Surg 2016 Ann Scientific Meeting Washington DC Oct 2016

13) **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. Abstract accepted to Military Health Services Research Symposium Aug 2016 for Podium Presentation

Invited Presentations:

1) **Colin Mackenzie: Title: Evaluation of Individual Surgeon Technical Skills During Four Emergency Procedures.**
   Podium lecture Assoc Military Surg of US Nov 2014 Washington DC

2) **Colin Mackenzie: Title: Department of Defense Special Presentation Panel at Society for Simulation in Healthcare** Title: Minimizing Clinical Skills Decay.
   Podium Presentation and Panel Member Jan 16 2016.
3) **Colin Mackenzie: Department of Anesthesiology Grand Rounds, University of Maryland School of Medicine.** Title: Never mind the anaesthetic: How good is your surgeon? February 16th 2016.
4) **Colin F Mackenzie US Army Ft Detrick: Briefing Col Rasmussen on overall project. April 13th 2016**
5) **Colin F Mackenzie: National Institutes of Health.** Bethesda MD. Presentation and Panel Member June 10th 2016 Simulation Research in Gastrointestinal and Urological Care: Challenges and Opportunities

List of Tables: (Table legends are in bold through the text and placed above the related table)

OSATS = Objective Structured Assessment of Technical Skills; PA = Psychomotor Aptitude; PBA = Procedure Based Assessment; QADAS 2 = Quality Assessment of Diagnostic Accuracy Studies; RCT = Randomized Clinical Trial; SAVE = Structured Assessment of Endovascular Expertise; VSP = Visual

showing a complete script for the Axillary Artery exposure procedure. Table 7.1 shows the commonalities of IPS across Axillary Artery, Brachial Artery, and Femoral Artery scripts.

Table 7.2: Intra-Class Correlation Coefficients (ICC) for components of Individual Procedure Score (IPS) and for IPS for each of Axillary, Brachial, and Femoral Artery by pairs of evaluators before and after training.

Table 7.3: Comparison of Individual Procedure Score (IPS) components before (Pre) and after (Post) training for Axillary, Brachial, Femoral artery exposures and a pooled trauma vascular readiness index using linear mixed models. Note all performance metrics are significantly different after training ($p< 0.001$) with the exception of Management components (not part of training). TRI= comprehensive IPS for axillary, brachial and femoral arteries = Trauma vascular readiness index.

Table 7.4: Objective components of Individual Procedure Score assessing steps in the vascular exposure for axillary, brachial and femoral arteries are shown, before (Pre) and after (Post) training and the difference (diff). All vascular exposure and control metrics are significantly improved with ASSET training ($p< 0.001$) using linear mixed model (procedure time, landmarks) and general linear mixed models for binary data.

Table 7.5: Pearson Correlation coefficients (r) before (Pre) and after (Post) training of Individual Procedure Scores (IPS) for performance of axillary artery (AA), brachial artery (BA) and femoral artery (FA) vascular exposure, in comparison to five subjective independently scored global ratings (overall performance, management, anatomy, technical skills and readiness to independently perform the procedures). Italics show $p < 0.001$ [$\alpha=0.05$] identifying that all subjective global ratings except FA Post are significantly different than the objective metrics included in IPS

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Figure 5.2: Histogram of the frequency (y-axis) of each numbered Likert scale response (x-axis) provided by the self-assessment of the 42 residents compared with the expert evaluators' global assessment for exposure and control of the brachial artery. The percentages of each of the frequencies are listed above each Likert scale response. Sixty-nine percent (%) of residents received a score of 2 or less by evaluators, and residents tended to rate themselves higher.

Figure 5.3: Histogram of the frequency (y-axis) of each numbered Likert scale response (x-axis) provided by the self-assessment of the 42 residents compared with the expert evaluators' global assessment for exposure and control of the femoral artery. The relative percentages of each of the frequencies are listed above each Likert scale response. Sixty-five percent (%) of residents received a score of 2 or less by evaluators, and residents rated themselves significantly higher.

Figure 6.1: Individual Procedure Score (IPS %) on Y Axis is plotted against components of IPS on X axis. Hatched = Pre- ASSET Training , Open = Post-Asset Training in 12 surgeons.

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Figure 7.4: When error occurrence on Y axis is plotted against Adjusted IPS (Adjusted IPS metric has no errors or time errors included) an exponential increase in errors occurs when adjusted IPS goes below about decile 6 (60%) of the resident surgeon cohort Inividual Procedure Score.

*Figure 7.5***:** *Left Panel: Comparison of critical errors (e.g. passed vessel loop around median nerve instead of brachial artery) in 40 residents and Fellows Pre-Post ASSET training Red histogram represents uncorrected errors, Blue histogram represents errors that were self-recognized and successfully corrected. There was a significant ($p <0.001$) reduction in errors in the 40 surgeons as a result of training and a significant increase in error self-recognition ($p <0.025$) with the one-day ASSET training.*

Figure 7.6: Left panel: improvement in IPS Procedural Skill plotted as a function of initial score. The higher the initial IPS the less the percent improvement is. Curve intersects at 0.6 and

predicts scores greater than this do not improve with training. Right panel: improvement in correct landmark identification scores shows an intersect at 0.8. Higher intersect than procedural steps suggests training in correct landmarks maybe the most valuable training intervention. These data may be sufficient to predict how "valuable" training will be and what sort of training is needed.

Figure 7.7: Top Panel: Shows item analysis of 24 questions answered correctly for AA Anatomy (Top Panel) in 40 surgeons. Complete script for AA is in Appendix II. Blue histograms represent Pre ASSET training responses among 40 surgeons and Red histograms represent the responses by the same surgeons after ASSET training. In Bottom Panel: Correct Procedural Steps in 13 evaluation steps related to landmark sand incision placement, AA vessel identification in same 40 surgeons as Top Panel. Blue represents Pre-ASSET and Red histograms after taking the ASSET course

Figure 7.8: In 12 surgeons , self- reported confidence in performing upper and lower extremity vascular control procedures were obtained four times. These are plotted before and after the initial study evaluations and then before and after Advanced Surgical Skills Exposure for Trauma (ASSET) training. For lower extremity procedures confidence appeared to fall after the first evaluation before ASSET training.

Figure 8.1: IPS scores by co-located evaluators are on the Y axis and evaluation visit time is shown on the X axis, All 40 surgeons' performance data are individually plotted pre and post training follow-up after taking the ASSET course. Overlaid in blue red and green plots are the lower, middle and highest tertiles of pre- training IPS scores. For the purposes of preparation of video clips for blind video review, one surgeon was randomly selected from each tertile for each for each procedure (see text).

Figure 8.2: Blind Video Review Individual Procedure Scores on Y axis are plotted against surgeon (#1-9) on the X axis. Each surgeon 1-9 had their video randomly selected as representatives on each tertile of IPS performance evaluated before ASET training. The red cross symbols represent the Pre training blind video IPS and the blue circle symbols represent

the Post- training blind video IPS of the same surgeons. No single surgeon was evaluated for more than one procedure. Each procedure among AA BA and FA had a different group of 3 surgeons. Star symbols represent an identical score by more than one blind video reviewer.

Figure 8.3: Correlations of 5 video reviewers evaluating 12 surgeons performing 3 procedures. Y axis video Individual Procedure Score (IPS), X axis mean of two Co-Located IPS scores of same surgeons performing the same procedures. From Top Left Clockwise: Axillary Artery (AA), Brachial Artery (BA), and Femoral Artery (FA). IPS for Video review and co-located Pearson correlations (R) for all 3 procedures considered together for the same surgeon was 0.86 for Pre training evaluation and 0.79 for post training

THESIS CONTENTS:

CHAPTER 1: Background to Surgical Training, Haemorrhage Control and Performance for Open Vascular Exposure and control of the extremities: Rationale, Hypotheses and Aims of Thesis.

1.0: Problem Addressed and Overarching Aim of Thesis:

Surgical patient outcomes are related to technical and non-technical skills of the surgeon. Such skills are important in emergency trauma surgery because injury may occur in any body location. Trauma does not respect, but instead destroys normal tissue planes and anatomic relationships. Emergency trauma surgery is therefore extremely challenging and potentially error-prone. Trauma patient operative and management experience has declined since trainee duty-hour restrictions were mandated in 2003. It is increasingly clear that current surgical trainees receive a very limited exposure to the operative management of vascular trauma and that specialists are graduating, who when called on to care for victims of trauma may or may not have the requisite skill set to ensure optimal outcomes. As such there is a critical need to change the way surgeons caring for trauma are trained and their skills are maintained. The Advanced Surgical Skills for Exposure in Trauma (ASSET) cadaver-based course, teaching vascular exposure and haemorrhage control, was developed to fill this training gap. Although the one-day cadaver-based ASSET course was developed by the American College of Surgeons Committee on Trauma, any benefits of ASSET training have not been validated. The overarching aim of this Thesis is to develop surgeon performance metrics and to test surgeons before and after taking the ASSET course to determine whether such training improves performance of peripheral vascular control. The overall Thesis Plan is shown in Figure 1.0 (below).

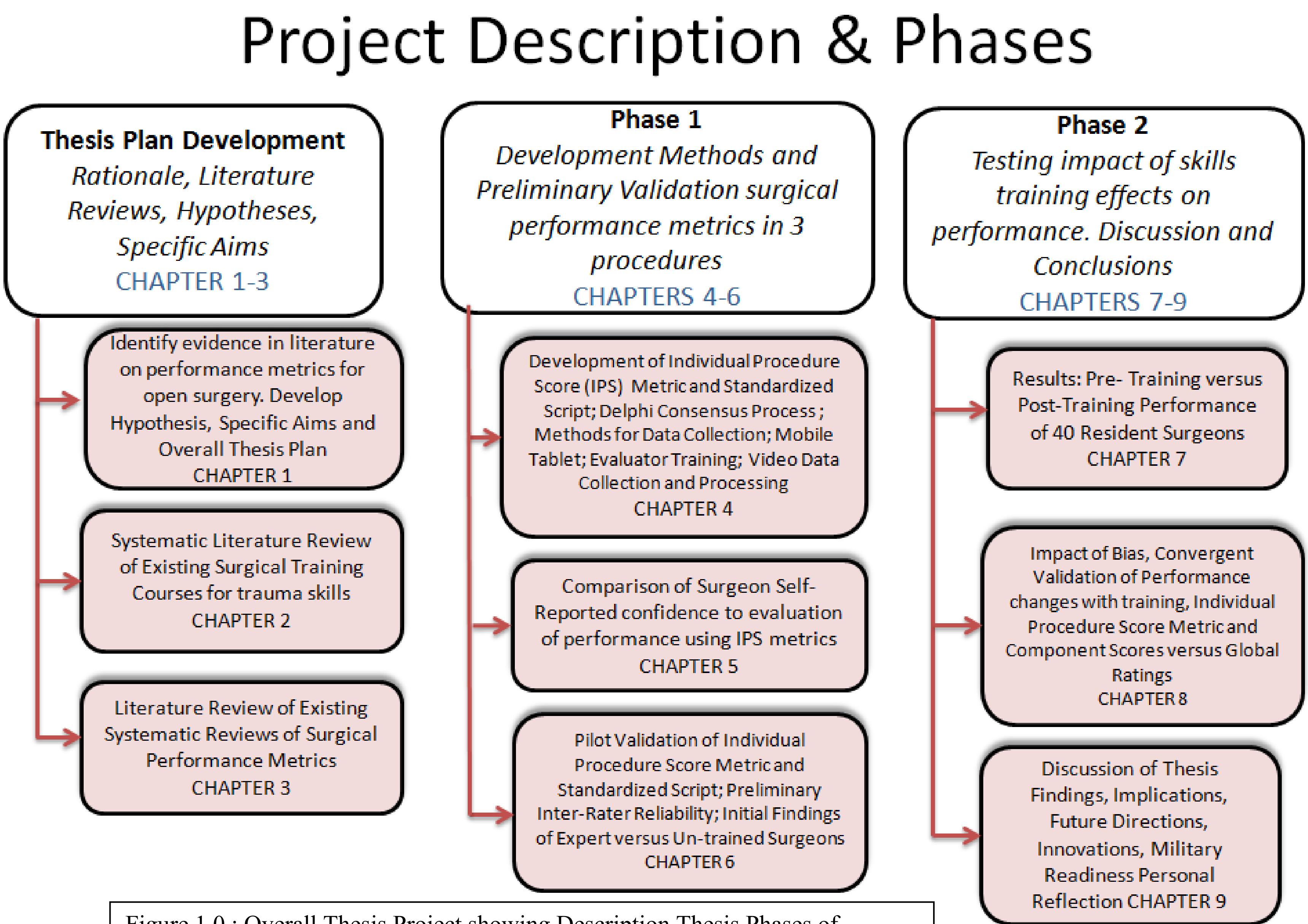


Figure 1.0 : Overall Thesis Project showing Description Thesis Phases of Development, Phase I and Phase 2 (in White Boxes. Chapter specific details of each Phase are shown in lower Pink Boxes

1.1: Surgery for Trauma:

Uncontrolled bleeding (haemorrhage) is responsible for two-thirds of the 4.3 million deaths worldwide that occur annually, as a result of traumatic injury (3, 4). Early and aggressive interventions to control bleeding improves survival (5, 6). Thirty thousand patients die in United States (US) hospitals alone each year from injury (7). Between October 2001 and June 2011, of 4,596 US battlefield fatalities, acute mortality was largely associated with haemorrhage (90.9%). The site of lethal haemorrhage in military deaths occurring from acute trauma-related bleeding was truncal (67.3%), followed by junctional (19.2%) and peripheral-extremity (13.5%) haemorrhage (8). Half of these US deaths occur in the first minutes after injury, the result of massive disruption of central vessels, or of the heart itself, with subsequent rapid exsanguination. Deaths from haemorrhage occur predominantly in the first 12 hours after injury, in patients who have survived long enough to be admitted into the emergency medical system. Deaths beyond 12 hours are rarely due to acute bleeding (9). Management of bleeding involves rapid control of the source and restoration of normal tissue perfusion. Therapy is focused on diagnosing the anatomic location of injury and application of external pressure until definitive surgical control of blood supply can be achieved proximal to the site of injury.

1.2: Capability Gap in Evaluation of Haemorrhage Control Performance and Military Preparedness:

A fundamental capability gap exists for determining whether surgeon performance benefits from training in specific rarely-performed procedures. Multiple different surgeon training techniques are available. These include defined surgical training programs to individual training courses or practicing of simulated surgical sub-task technical skills such as knot tying. The traditional approach is to evaluate training with the pyramid framework proposed by Miller in 1990 (10) for assessing clinical competence: “knows, knows how, shows how and does”. For evaluating “does”, procedure based assessments (PBA) are used in the United Kingdom (UK) to evaluate surgeons performing elective surgical procedures as members of an operating team (13, 14). Because adequacy of surgeon operating skills are currently a focus of concern due to the shortened training hours and limited exposure to clinical operative participation, evaluation of surgeons-in-training is necessary. The Royal College of Surgeons and the Intercollegiate Surgical Curriculum Programme have developed Procedure Based Assessments (PBA's) (11, 12) of Surgical Skills. In the US, operative competency assessments (including, technical and non-technical skills) were developed. Reaching these levels of competency is used to inform progress of surgical resident's advancement through training. The need for measurement of outcome from training interventions requires testing, as opposed to relying on the subjective "good guy, bad guy "evaluations of surgeon competency previously used (13). Knowledge based testing does not confirm surgeon operative competence. The relationship between the American Board of Surgery In-Training Examination (ABSITE), skill testing, and intraoperative assessment showed that the In-Training Exam results measured knowledge, but the testing results did not correlate with technical skills or operative performance (13).

1.3: Why is it important to examine training in surgical skills?

Total US surgical resident training hours have been reduced from 30,000 to less than 20,000 hours with the ACGME mandate (14). There has been a similar reduction in training hours in the UK (15). As a result there is concern about surgeon's lack of surgical skills, limited experience and decline in these skills over time since training. In the UK the General Medical Council's (GMC) Performance Procedures (PPs) require surgeons whose performance has been questioned to undergo competency assessment. Phase 1 of PPs is an assessment in the workplace by two medical assessors and one lay assessor and Phase 2 a generic performance evaluation in a simulated environment (15, 16). The work for this Thesis took place in the US, so while the domain is different, the impact of similar reductions in surgeon training is, in principle the same, for core surgical skills (such as vascular exposure and haemorrhage control) whether the surgeon operates in the UK or US. My Thesis will describe how training can be used to optimize bleeding control, the major clinical problem causing potentially preventable early death after injury throughout the world, including military conflicts. I will use the Advanced Surgical Skills Exposures in Trauma (ASSET) course developed by the American College of Surgeons Committee on Trauma as the training model of surgical performance for trauma related emergency vascular exposure and control procedures (17, 18). My Thesis assess whether the one day course can improve performance of vascular exposure and control. I will describe development, validation and testing of performance assessment tools (Fig 1.0) to determine whether surgeon performance is improved by the ASSET course and to identify specific features of the course that show particular benefit and may be amenable to future training interventions to ensure retention of these skills.

1.4: Peripheral Vessel Exposure and Repair for Injury:

Peripheral vessel exposure is an ABS core competency procedure. Specifically, axillary, brachial and femoral vessel injuries are the focus of my Thesis. Peripheral vessel injuries are of increased recent interest because (8) of improvised explosive device (IED) blast injuries, sustained peripheral to the body- armour protected torso. The need to rapidly expose, gain proximal vascular control and repair such bleeding vessels is an important life–saving surgical manoeuver, because uncontrolled exsanguination is a major cause of preventable death in the modern battlefield (2). Training in haemorrhage control is important because the rate of vascular injury in modern combat is five times that reported in previous wars (19). Vascular injury of the extremities represent between 50% and 70% of all injuries treated during Operation Iraqi Freedom, and exsanguination from extremity wounds is the leading cause of preventable death on the modern battlefield (20, 21). Among 1570 combat casualties with vascular injuries in Iraq and Afghanistan, 60% of these injuries were to major or proximal vessels (21). In the lower extremity, femoral injuries are more prevalent than other vessels (19), and upper extremity vascular injuries involve the axillary artery in 23% and the brachial artery in 58% of cases involving injury to the upper extremity (20).

1.5: General Problem of Inadequate Haemorrhage Control:

In situations of peripheral arterial bleeding, the source maybe obvious, and control can be achieved with tourniquets proximal to the bleeding site until definitive surgical repair can be achieved. In other cases, bleeding control may be more difficult to achieve (e.g. non-compressible torso haemorrhage, severe pelvic trauma) or diffuse (small-vessel bleeding due to lack of blood coagulation factors). Definitive resuscitation is unlikely to be successful unless the source of arterial bleeding is first controlled or coagulation restored (9). Anecdotal evidence from as far back as World War I supported the futility of fluid administration to counteract blood loss and hypotension before control of haemorrhage in combat (9). Dr. Walter P. Cannon, a US surgeon, was one of the first to attempt intravenous resuscitation of wounded soldiers. His observation in 1920: "Haemorrhage in the case of shock may not have occurred to a marked degree because blood pressure has been too low and flow too scant to overcome the obstacle offered by a clot. If the [blood] pressure is raised before the surgeon is ready to check any bleeding that may take place, blood that is sorely needed may be lost." remains important even today (22). Similar experience arose during World War II. The US Office of the Surgeon General published the following recommendation in 1952: "When internal haemorrhage persisted, for instance, there could be no resuscitation without surgery and it was wasteful of both time and blood to attempt to raise the patient's blood pressure to normal before operation. The blood or plasma which was administered merely leaked into the traumatized regions and was wasted . . ."(23) Despite similar anecdotal experience during the Korea and Vietnam wars, it has taken a long time to re-learn the lesson that surgical control of bleeding should occur before aggressive resuscitation (9). Clot disruption by increased blood pressure due to fluid resuscitation perpetuates bleeding. The need for definitive fluid resuscitation to normalize blood pressure after haemorrhage was in part due to Shires work (24), and in part to the unproven theory that too much fluid would be safer than too little (9).

1.6: The Military Surgeon Requirements:

In 2010, (25) the future needs for military medical preparedness were evaluated. Included in the recommendations were increased training of combat medics to provide a higher level of care, equivalent to Advanced Trauma Life Support (ATLS) training. The recommendations included ATLS at the point of injury together with standardized treatment and triage protocols. In comparing deaths from 2003 and 2004 to deaths in 2006 in the Iraqi conflicts (26), Kelly et al found 83% of potentially survivable injuries, were due to haemorrhage. Among these, 49% were non-compressible torso haemorrhage, 21% were haemorrhage not amenable to tourniquet placement (axillary, neck and groin regions), and 33% were haemorrhage amenable to tourniquet placement. Overall, these data suggest that some deaths from penetrating torso injury, possibly up to 50%, are potentially salvageable by an immediately available and appropriately placed surgical team, expert at vascular access and haemorrhage control.

The challenge facing US and UK civilian and military training institutions is sustaining the current level of expertise. Fewer opportunities exist for general surgery trainees to perform open vascular procedures and for deployed military surgeons to have legitimate vascular training to ensure battlefield readiness. The number of vascular operations performed by general surgery residents have declined by 50% since 2009 (27-29). Furthermore vascular surgical residencies, the emergence of acute care surgery and interventional endovascular radiology have minimized general surgeon's vascular training experience. Because of their lack of experience, surgeons in small and mid-sized hospitals who previously were trained in management of vascular injury, now make referrals to "Centres of Excellence" for management (30, 31). Many military surgeons are ill prepared to care for combat-associated injury. Likewise, there is no current measure against which to assess the durability or degradation of these skills once obtained, particularly after return to peacetime practice, where these skills are unlikely to be used with any frequency. Given this picture of decreasing operative experience, surgeons deploying to care for combat casualties must be proficient in the exposure and control of major vascular injuries. 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 (32), so that interval assessment of trauma specific surgical skills over time is needed to ensure that previously trained surgeons remain prepared for deployment.

1.7: Logistical Challenges beyond Training for Reducing Preventable Deaths from Haemorrhage:

There are other factors besides surgeon competence that will impact casualty survival. Morbidity and mortality outcomes for casualties in Afghanistan were compared before versus after a mandate for evacuation of all casualties within 60 minutes (33). Examination of 21,089 US military casualties that occurred during the Afghanistan conflict showed the percentage killed in action and the case fatality were higher before compared to after the mandate, while the percentage died of wounds remained unchanged. Decline in fatality rate after the 60 minute evacuation mandate was associated with an increasing percentage of casualties transported in 60 minutes or less equating to 359 lives saved. Among 4542 casualties with detailed data, there was a decrease in median transport time after the mandate from 90 min to 43 min and an increase in missions achieving prehospital helicopter transport in 60 minutes or less. Acute morbidity was higher among those critically injured who were transported in 60 minutes or less, those severely and critically injured initially treated at combat support hospitals; and critically injured casualties who received a blood transfusion. These data analyses emphasized the need for timely advanced treatment (33). Not only skill of the providers, but pre-hospital transport time and treatment capability are important factors for casualty survival on the battlefield. Reduced pre-hospital transport time is also a factor increasing survival in civilian practice, separate to competent performance of surgical control of haemorrhage.

1.8: Surgical Training in the United States (US):

Surgical training in the US occurs over a minimum of 5 years with a structured curriculum. Surgical programs are rigorously accredited on a 2- 5 year cycle by the Accreditation Council for Graduate Medical Education (ACGME). The traditional surgical training model of graded clinical responsibility became outmoded because of restrictions in surgeon training hours mandated in 2003 by the ACGME. Six clinical competencies in surgery have been introduced by the American Board of Surgery (ABS www.absurgery.org) , including competencies in Professionalism, Patient Care and Procedural Skills, Medical Knowledge , Practice-based learning, Systems Based Practice, Interpersonal and Communication Skills. Surgical resident training in a general surgery program accredited by ACGME is required to be progressive and to take place at no more than 3 different ACGME accredited residency training programs. ACGME sets standards for residency programs. Noncompliance with ACS standards results in probation. Ultimate failure to meet standards can result in the program losing accreditation (14). Surgical training requires at least 48 weeks of full-time clinical activity in each residency year, regardless of the amount of operative experience obtained. At least 54 months of clinical surgical experience with increasing levels of responsibility is required over the 5 years, with no fewer than 42 months devoted to the content areas of general surgery. During all junior post-graduate years (PGY) 1-3, no more than 6 months can be assigned to non-clinical or non-surgical disciplines, and no more than 12 months allocated to any one surgical specialty, other than general surgery. The final two residency years must be in the same training program. Specific requirements for completion of surgical residency training include: - At least 6 operative and 6 clinical performance assessments conducted by the program director or other faculty members while in residency. The residency ends with a Chief Surgical Resident year. During this year, the resident has ultimate clinical responsibility for patient care, under the supervision of the teaching staff. The senior resident is involved with the direct care of the patient in general surgery for a 12-month period. All rotations at the PGY-4 and -5 levels involve substantive major operative experience and independent decision making. Since 2003, surgical resident duty hours have been limited to about 60 hours per week..

1.8.1: Operative Experience Required Since 2003 ACGME Mandate:

A minimum of 750 operative procedures in five years are required as the operating surgeon, including at least 150 in the chief resident year. Up to 50 operative cases may be counted towards this 750 total when the resident acts as a teaching assistant. There is an interval time course stipulation that a minimum of 250 operations must be completed by the end of the PGY-2 year.

1.8.2: Surgical Council of Resident Education (SCORE):

The SCORE Portal (www.surgicalcore.org) provides educational content and assessment in support of the ABS curriculum to general surgery residency programs. Learning “modules” are available on the portal for nearly all of the topics. Modules on the portal contain learning objectives, study questions and a variety of resource materials, including textbook chapters, videos and radiologic images. Multiple-choice questions are also available to assess resident knowledge. The ABS operative competencies include the broad categories of surgeon technical and non-technical skills. Technical skills include surgical instrument handling, anatomy, specific procedural steps, dexterity and efficiency of surgeon hand motions and technical skills associated with surgical sub-tasks such as knot tying and suturing. Non-Technical Skills include other ABS competencies described above including Professionalism, Medical Knowledge, Interpersonal and Communication Skills. Among the ABS Technical skill competencies are Procedural Skills. Included among the core procedural skills are Truncal and Peripheral Vessel Repair for Injury, the subject matter of my Thesis.

1.9: Background Significance of Evaluating Surgeon Technical Skills Performance:

The declaration of the original charter of the Royal College of Surgeons of Edinburgh in 1512, included a statement that surgeon's skills should be periodically evaluated (34). It has been estimated that the introduction in the United Kingdom (UK) of the Modernising Medical Careers initiative (35) in response to the Calman Report (36) , the European Working Time Directive (34, 35, 37) and the US Accreditation Council for Graduate Medical Education limitation of duty hours requirement (38) effectively resulted in a reduction of surgical trainees clinical experience from about 30,000 to less than 20,000 hours or in some reports even as low as 8-9,000 hours (35). It has therefore become necessary for surgeons to show competence in technical skills, since these skills are not evaluated in either written or oral examination (38). However, success in these examinations provides approval to practice surgery as a Consultant or Attending surgeon independently, unsupervised and unrestricted and to operate without further training and to bill patients for these services (34). The operative log book and direct observation of procedural skills are used to assess surgical competence, but these are subjective, unreliable, lack specific criteria, have little precision and can be biased. The reason such subjective assessments are still used to judge surgeons skills for open surgical procedures is because there is limited work published on assessing surgical performance for open surgical procedures, although there is a body of published work on performance of laparoscopic technical skills, surgical teamwork, and surgeon non-technical skills (39-43). Novel ways of increasing surgical training efficiency are urgently needed. Since the 2003 ACGME mandate, there is increased use of surgical simulation for use in operating room skills training, to benchmark competent performance.

1.9.1: Capability Gap in US Surgical Residents:

Vascular surgery is considered an integral part of general surgery training, however, there is a large training gap for trauma surgery according to ABS data, as fewer graduating US surgical residents report or can document experience caring for vascular trauma (44, 45). Over the last ten years, the average number of major vascular repairs for trauma (includes repair of thoracic aorta, innominate, subclavian, neck vessels, abdominal aorta, peripheral and other vascular injuries) by graduating chief residents reported to the ABS decreased from 5.0 in 2001-2002 to 2.1 in 2010-

2011 over the course of a 5 year residency in general surgery (46), and these numbers are averages. Significant numbers of trainees have no experience whatsoever with caring for major vascular trauma. A recent 20-year review of ACGME case logs demonstrated that graduating chief residents performed half the number of designated trauma operations (39.4 ± 21) compared with those of two decades ago (72.5 ± 46) (46). The average number of operative cases for vascular trauma (all vessels) over a 5-year residency was reported as only 2.1, with exposure and repair of peripheral arteries reported as 1.0. Additionally, non-traumatic vascular experience is also limited with average numbers of cases involving any exposure of the axillary artery at 0.6, open brachial artery exposure at 0.1, and femoral artery at approximately 10.0. The National Resident Report also lists operative experiences in which the brachial artery might be exposed, namely arteriovenous fistulas and grafts, as well as with revision of arteriovenous access with averages of 17.7, 6.6, and 6.3 over a 5-year residency (47). This limited experience is of great concern in gaining surgical competence (48-51). An additional consequence of declining experience is a decrease in surgeons' confidence to manage injuries and the potential increase in morbidity and mortality (51).

1.9.2: Endovascular Perspective on Haemorrhage Control:

Endovascular techniques are increasingly used to treat vascular injury and age-related diseases (27, 30). As a result the numbers of open vascular procedures available for education of general surgeons has decreased dramatically. When 520 trauma (n= 307) vascular (n= 90) and general surgeons (n= 99) were surveyed, less than 10% of general surgeons managed vascular injuries at their institutions. Few general or trauma surgeons possessed an endovascular catheter-based skill set, and 25% of vascular injuries at the respective institutions were managed by non-surgeon interventional radiologists. The rapid evolution of endovascular therapies for trauma comes at a time when surgeons in-training have limited exposure in vascular control and the trauma surgeons lack catheter-based endovascular skills to control haemorrhage (30). Tourniquets remain a viable option for vascular control of minor or distal injuries, because tourniquet complications are minimized if rapid evacuation occurs. Traditional vascular exposure and proximal and distal control and ligation can be life-saving and can be augmented with damage control shunting and repair of distal vascular injuries, so enabling later limb salvage and reducing morbidity and mortality. Restoration of perfusion within one hour is necessary to achieve neuro-muscular recovery, and temporary shunts can extend the time to achieve successful limb salvage (30).

1.10: Advanced Surgical Skills for Exposure in Trauma (ASSET) Course:

The American College of Surgeons Committee on Trauma leadership established a Surgical Skills Committee in 2005. This committee was charged with developing a standardized, skills-based cadaver course designed to teach surgical exposure of vital structures that are most likely to pose an immediate threat to life or limb when injured (51),(18). The result of this effort was that the first Advanced Surgical Skills for Exposure in Trauma (ASSET) course was offered in March 2010. The ASSET Course was developed specifically to address the vascular trauma training deficits noted above. ASSET is a one day, case-based, scenario-driven dissection course using unpreserved cadavers and emphasizing surgical exposure of extremity, neck, chest, abdomen, and pelvic vasculature, with additional instruction in fasciotomies and pelvic packing.

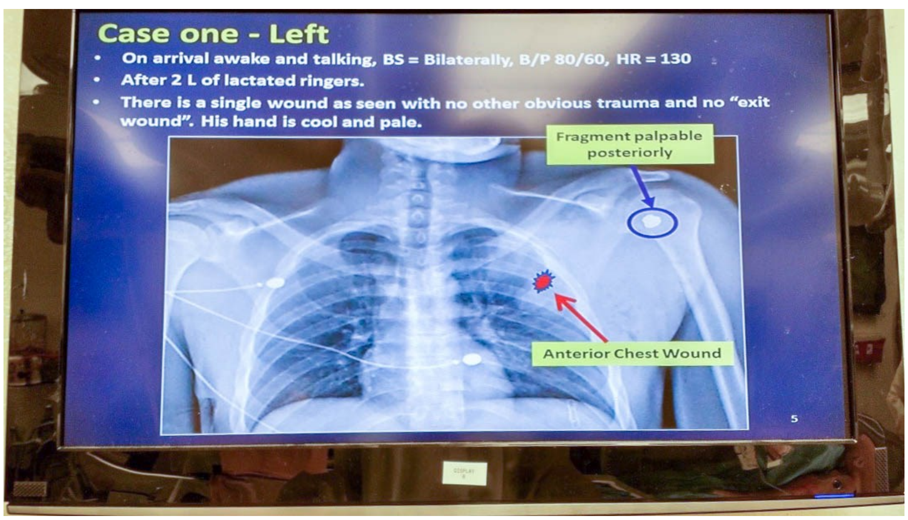


Figure 1.1: Slide from the Axillary Artery injury case presentation in the ASSET Course. Slides sequentially provide updated clinical information. Slides are displayed on wall-mounted screen in the Cadaver Laboratory.

The ASSET course was initially developed for civilian surgeons, the course now includes vascular exposure skills essential to the optimal management of combat wounded casualties. The ASSET course was recently incorporated into the Emergency War Surgery course as a replacement for the cadaver portion of the curriculum. Since the course began, there have been over 100 ASSET courses conducted at 80 sites across the US Canada and other countries, with approximately 1500 students trained, many of whom have been military surgeons attending pre-deployment training. The ASSET course is conducted regularly at the State Anatomy Board located at the University of Maryland School of Medicine, an example of participants in such a Maryland ASSET course is shown in the image below:

Figure 1.2: An ASSET course being conducted at the State Anatomy Board situated in the University of Maryland School of Medicine.

The course has been well-received by surgeons at all levels. A recent review of 25 ASSET courses (51) included 214 senior surgical trainees and practicing surgeons who were asked at baseline and upon course completion to assess their comfort level with 59 separate skills included in the curriculum. The improvement over baseline was highly significant for all 59 skills. Students were asked to evaluate the course and reported (on the 5 point Likert scale) gaining new knowledge (4.82); learning new techniques (4.83); being better prepared to expose injured structures (4.88); felt course was appropriate to their level of training (4.75); and would recommend the course to a colleague (4.92)(51). Though all of the skills taught in the ASSET course are important to the deploying military surgeon, based upon the patterns of wartime vascular injury, the surgical skills likely to be of most benefit are exposures of the axillary, brachial and femoral arteries. In the current Afghanistan and Iraqi conflicts the torso is somewhat protected with body armour, it is the extremities that are exposed to injuries. As such, these three skills and ASSET course training were chosen as targets for study of surgeon performance in this Thesis.

1.11: Measuring Trauma Surgical Technical Skills:

The three most common training intervention strategies employed are didactic lectures (to provide factual information), demonstration-based training (where trainees observe the required skills e.g. in the operating room or videos) and practice based training (e.g. surgeon-assistant in the operating room or simulation). Simulation-based training is used extensively in many industries (e.g. aviation, military) to train both technical and non-technical skills. As noted by Hull (52) there is increasing recognition that the operating room has limitations as an ideal learning environment because of patient safety, ethical and logistical reasons. In the operating room, optimum surgical management, not the acquisition and mastery of surgical skills, is the main priority. Simulation has been suggested as a complementary training environment to clinical practice, (53-55) offering the advantage of allowing surgeons to learn technical, non-technical, and team skills in an structured learning environment, where failures are allowed (56) and mistakes, which are particularly high in the early phases of the learning curve, do not jeopardize patient safety (53). Trauma surgical training remains a core competency of general surgery residencies, however as previously described, and for the reasons discussed, opportunities to train and develop trauma specific surgical skills have decreased over the past decade.

1.11.1: Surgical Simulation:

Advances in simulation training have occurred, offering a potential mechanism to measure surgical skills training. Simulation training options include virtual reality trainers,(57-60) models or manikins,(61-63), human cadaver training (51, 64-66),and animal laboratories (67-69). A number of surgical skills assessment methods have been developed over the past decade that include the general categories of task-specific checklists, global rating scales, procedure-specific rating scales, and non-technical skills assessments (70-72). An objective method of assessing competency in surgical skills specific to trauma surgery would be very beneficial to surgical training programs. Manual dexterity parameters were summarized by Hull (73), including time to complete the task/operation,(74), (75), (76), (77),(78), economy of motion, (79),(80, 81) tool movement smoothness, (82),(83) instrument smoothness, (76) hand movement, (82), (83) instrument path length, (76, 84) gesture proficiency, (82) hand motion efficiency (85, 86).

Sensor-free Computer-Vision hand-motion entropy and video-analysis of technical performance has been used to assess technical performance of individual operators during open surgery. Many studies rely on synthetic models or partial tasks to simplify the hand motion analysis (87-94) or focus on endoscopic or specialized environments (90, 94). Multiple reports have described tools to measure and track hand motion during rigid endoscopy (e.g. laparoscopy, arthroscopy) (90, 94, 95), and during use of robotic surgery devices (96, 97). Tracking hand motions while using flexible endoscopes is more difficult, since operator hand movements do not translate directly into movement of the distal end of the flexible endoscope, especially in mobile environments such as the colon (98). Hand movement tracking data is useful to assist intraoperative navigation to position acetabular implants (97, 99) and for quantifying the benefits of training. Open surgical procedures vary widely, requiring novel 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. Few studies evaluate open surgical procedures because capturing hand movement in this setting is more complex (90). Hand-motion analysis has potential as an unbiased, accurate, and cost-effective means to evaluate surgeon technical performance. Automated, such assessment would enable skills evaluations to be integrated into residency training, providing immediate feedback and minimizing reinforcement of errors (99). 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 (85-92).

1.11.2: Quality of Technical Performance:

All performance assessments have inherent strengths and flaws. An ideal assessment uses multiple methods to capture different aspects of performance, balancing the use of complex ambiguous real-life situations with simplified structured and focused assessments (100). Quality of surgical technical performance can be assessed by a number of different methods including procedural duration and final product quality (75, 78, 101). Other approaches examine number of errors (76, 79, 81, 83, 102). A systematic approach to examine technical errors in video recordings of performance is the Observational Clinical Human Reliability Analysis (OCHRA) (42, 103, 104), and it was found to be a valid tool for assessing competency at a specialist level in advanced laparoscopic surgery. An assessment tool used commonly to capture quality of technical performance is Objective Structured Assessment of Technical Skills (OSATS) (41, 86, 101, 105, 106) that includes both global rating scales and checklists. The Mini Objective Structured Assessment of Technical Skills (MOSAT) (107) is a global rating score based on OSATS. Both OSATS and MOSAT are not designed specifically to asses trauma related procedures or vascular exposure and control skills. Checklists can be used in the form of task-specific checklists (85, 107-109) or essential-item checklist (41), or procedure-specific skill (108). These checklists identifying procedural problems were combined with occurrences of errors as the NOPEs metric (Non-Operative Procedural Errors: NOPEs) (42, 73, 110). For purposes of approaching the ideal assessment of technical performance, the commonalties among these different approaches include both task and procedure specific checklists, global rating scales, errors. In emergency procedures, the duration of surgery to a defined end-point is a useful additional metric.

1.12: What Performance Metrics are Lacking?

Specific performance metrics for acquisition of combat surgical technical skills are lacking. Existing validated metrics for surgical performance, such as Objective Structured Assessment of

Technical Skill (OSATS) (111) are not directed at trauma surgery. There is ample evidence that individual surgeon technical skills are critical to successful surgery, independent of the non-technical and technical skills of the surgical team as a whole. A pivotal article in 2013 published in the New England Journal of Medicine (112) directly linked individual surgeon technical surgical skills in bariatric surgery to surgical complication rates. The authors asked 20 practicing bariatric surgeons in Michigan to choose video recordings of themselves performing laparoscopic bariatric surgical procedures. These videos were reviewed by a panel of surgical peers and scored using an OSATS metric. Those surgeons who were scored in the top quartile of surgical skill compared to the lowest quartile of surgeons (who received about half the score of the top quartile) had fewer peri-operative complications, fewer re-operations and fewer post-operative complications, patient re-admissions and visits to the emergency department and lower mortality after all adjustments were made for case difficulty, co-morbidities etc. Until the advent of miniature video collection systems it had been difficult to gather objective data to evaluate surgeon's technical ability. It is clear from the 2013 Michigan surgeons' data that an individual surgeon's operative technical skill matters!

1.12.1: Validity of Technical Skills Metrics Based on Simulator Training:

Questions about the validity of simulator training for surgery reflect the lack of good data about what really happens in the process of performing surgical procedures. What data there are tend to focus on team, not individual surgeon performance (see Team Performance below). However, there is no consensus on the objective analysis of technical performance by clinicians (113). There are no accepted methods of evaluation of surgical performance for emergency open surgical procedures, nor is there agreement on how use of such metrics might improve clinical outcomes (43, 114). Observational research, including use of video recording, has been helpful for identifying recurrent and interrelated factors in communication and task performance.(115). Cognitive Work Analysis (CWA) is a Human Factors methodology which examines environmental (regulatory/workspace) social/organizational, individual, and technical constraints which characterize a training system (116). In previous work, I have used Cognitive Work and video task analysis to codify expert surgeon behaviour and planning during real trauma patient resuscitation procedures using extensive audio-video recording and analysis (117-119).

Cognitive Work Analysis includes so-called process-tracing (116, 120-122), that is, the recording of both "thinking out loud" and more formally structured didactics provided by experts while performing the tasks of interest. These structured and unstructured observations capture and provide a platform for measuring the complexity of individual expert performance (115, 122, 123). The rigor of such observation strategies has been improved by validating observational tools against best practice standards, using two simultaneous independent observers and triangulation of data using multiple data collection methods (124). However, longitudinal studies are needed to assess durability of skills taught in open surgical simulation and evaluations of transfer to assessments of real operating room performance are needed.

1.13: Individual Surgeon Non-technical Skills:

As examples of what is meant by non-technical surgical skills, Carthey et al (128) described characteristics of paediatric cardiac surgery excellence that could equally apply to trauma surgery including: self-belief, positive imagery, mental readiness, full focus, controlling distractions, learning from previous cases. Good paediatric surgeons anticipate potential pitfalls during the procedure. Eight behavioural markers of surgeon excellence at an individual level included 1) Technical skill [determines speed and precision of surgery], 2) Mental readiness [mental rehearsal, self-confidence, mental resilience even when faced with problems], 3) cognitive flexibility [ability to switch from one hypothesis to another], 4) anticipation [perception and response to potential events], including coordination, communication, leadership, team decision-making. Lack of these behaviours are major contributory factors in the causation of adverse events in healthcare and in surgery specifically. Studies in trauma resuscitation, intensive care, anaesthesia and surgery highlight that clinical skills are necessary but not sufficient to maintain high levels of performance in acute medical specialties. Improved methods to describe and assess non-technical skills for teams are needed, because especially in time-critical situations such as trauma patient resuscitation, leadership and communication. Observational Teamwork Assessment for Surgery (OTAS) (124, 129) are commonly used to describe performance of surgical teamwork. For gathering OTAS data, one observer monitors various non-technical tasks carried out by team members under five categories: patient, environment, equipment, provisions, and communications. At the same time, a second observer uses a behavioural scale to rate clinician behaviours for the three surgical phases (pre-operative,

operative, and post-operative) against five established components of teamwork: cooperation, leadership, coordination, awareness, and communication. Non-technical skills are clearly an important part of surgical performance, (52).The failure to report findings at the level of individual non-technical skills prevents firm conclusions being drawn regarding the contribution of each particular skill to technical outcome. In future it would be preferable to report specific skills of individual surgeons so that training interventions could be personalized by surgeon. This evaluation scheme would also identify the relative importance of each of these skills leading to overall training improvement. Previous reviews of non-technical skills among operating room teams show that they do have an effect on their technical performance (39, 125, 126). Hull suggests that "training to improve non-technical skills has the potential to improve teamwork, performance and safety in the operating room – and thus ultimately contribute positively to surgical technical performance and patient outcomes" (127). However, few papers report correlation between technical and non-technical skills.

1.14: Can Stressors Impact Surgeon Technical and Non-Technical Skills Performance?

A substantial body of research on stress and human performance shows that a certain amount of stress can improve performance by enhancing concentration and focus, but excessive stress compromises performance (40). Hull stated that "Despite the fact that coping with stress is an important non-technical skill, (40, 84, 125) as identified from a recent systematic review in this field, research on stress within surgery is sparse (126)". Four studies (81, 84, 85, 101) in the review by Arora et al (84) found that increased stress due to inexperience and unfamiliarity with a task was related to poorer technical performance. In contrast, a study assessing the impact of examination stress found that moderate increases in stress enhanced trainees' performance on a simulated task (85). The remaining two studies described by Arora focused on coping with stress (81, 101). The first study found that negative stress-coping strategies were associated with poorer laparoscopic performance on a virtual reality simulator (81), whereas the second found that enhanced coping strategies, even with multiple stressors, significantly improved the quality of the operative end-product (101). Coping with the deleterious impact of excessive levels of stress in the operating theatre is key to maintaining optimum technical proficiency (101, 125). The impact of stress depends on the level of expertise of the surgeon and the nature of the task (52, 101).

1.15: Hypotheses to be Tested and Thesis Aims:

My overall hypothesis is that trauma surgical performance measures can be developed, and validated to demonstrate the effectiveness of ASSET training in emergency vascular control procedures for extremity injuries.

In a two year, two-phase study (Phase 1 and Phase 2 described below), the hypothesis is addressed as three inter-related questions:

1.15.1: Three questions addressed by this Thesis are:

a) Do trauma surgical skills show improvement with training?
b) Which components among these skills benefit most from training?
c) Does training reduce the occurrence of error?

1.16: Aims Phase 1 and Phase 2:

Table 1.1 Flow Chart of Thesis Plan: Shows Under Column headings "When" in the Phase 1 or 2 of the Study Aims 1-8 the event occurred; "Who" was associated with this event; and "What" the event was and "Measurements used and Data generated" help explain the product of each Aim.

***When** :Phase 1*	***Who***	***What***	***Measurements Data Generated***
Aim 1 Cognitive task analysis of experts and novice surgeons. *Aim 2:* Literature review of existing trauma training courses and surgeon performance metrics	**Interview 3 expert surgeons identify** common pitfalls in AA, BA, FA exposure and vascular control 10 experts 10 Non-ASSET trained surgical residents	Thesis Rationale & Literature review to Develop metrics Video record of 10 Experts and 10 novice "Talk Aloud" during AA, BA, FA in fresh cadavers.	No data on phase 1 experts who were used to produce metrics for evaluation of Phase 2 surgeons. Individual procedure scores (IPS) defined for each of AA, BA, FA procedures.
Aim 3: **Develop a standardized script & Prelim testing**	**Five Experts**	**Consensus Conference** (discussion)	**Standardized script**
Aim 4: **Performance metrics Validate** with pilot studies.	Metrics Consensus conference participants.	Embed script in Mobile software **Train Evaluators:**	**Objective measures →Trauma Readiness Index**
Aim 5 **Inter-rater reliability testing (ICC).**	12 PGY2-6 year surgical residents evaluated pre and post asset training. 5 evaluators did blind video analysis.	**Testing metrics** Video Record Non-ASSET trained novices "Talk Aloud" during AA, BA, FA in fresh cadavers.	**Subjective Measures** ICC >0.7 included in before and after ASSET training
Phase 2: Aim 6 **Use validated IPS metric to test skills before and after ASSET course training.**	40 Non-ASSET trained novices (year 4-7 surgical residents and fellows)	Evaluations Pre and 2 weeks Post ASSET training Evaluations by one surgeon and one non-surgeon anatomist.	Surgical performance using developed IPS metrics
Aim 7: **Examine Study Biases**	Forty surgical residents; Video recording	Random selection of tertiles of performance before and after training	IPS by blind video review compared to co-located evaluation
*Aim 8:***Lessons Learned & Summary Conclusions**	Phases 1 and 2 studies.	Summarize important findings.	Thesis deliverables; Future Studies Overall conclusions.

In summary, Chapter 1 describes the training gap for haemorrhage control and why there is a need to develop performance metrics for open vascular surgical exposure and vascular control. US surgical residency training shows limited exposure of the current generation of surgical trainees to the kinds of injuries and proximal vascular control that are required to prevent excessive life-threatening haemorrhage from extremity injuries. My Thesis hypothesis and Aims were described. Chapter 2 will use a literature search to show none of these training courses have been validated to demonstrate training benefit.

CHAPTER 2: Literature Review of Surgical Skills Training Courses for Open Vascular Surgery.

2.0: Overview Chapter 2:

Chapter 2 describes the evidence of benefits from Surgical Skills Training Courses using Kirkpatrick's validation framework for evaluating these educational interventions. Despite there being numerous courses, there is no definitive source showing their benefit to surgical technical skill or transfer of these skills to enhanced operating room performance or to improved patient outcomes. According to Kirkpatrick's framework (130), each training intervention can potentially work at four levels of efficacy. Using this four level approach, the evidence in the literature was used to synthesise the validity of available courses. The aim of Chapter 2 is to conduct a literature review to identify currently available open surgical skills courses and models, and analyse the reported efficacy of surgical skills training and skills refresher courses with systematic abstraction from course publications to support each of the four Kirkpatrick Levels. The purpose of this evidence summary is to determine if there are existing performance measurement approaches in surgical skills training courses that could be useful in development of the metrics for trauma surgical performance to be used in this Thesis.

2.1: Methods for Literature Review of Trauma Skill Training Courses:

PubMed was searched using the terms: Trauma Training, Surgical Trauma Training, and Open Surgery (i.e. not laparoscopic, not endoscopic, not endovascular). Additional relevant articles were identified using Google Scholar and Ebsco's Discovery Service, as well as the University of Maryland's Health Sciences and Human Services Library's catalogue. Searches were complemented by a review of the reference lists of relevant studies found with these searches and by discussion with two surgeons who participated in the development or teaching of many of these trauma surgery training courses for civilian and military surgeons. Papers were included for review if they were designed for surgeon trauma skills training and excluded if the training was non-trauma, endovascular, endoscopic, laparoscopic or the course was only offered once or was designed to include physicians who were not surgeons, and/or were ancillary clinical staff such as nurses, pre-hospital providers or combat medics.

2.1.1: Kirkpatrick Framework for Structuring the Results:

The framework for describing the results of the search used the approach developed by Kirkpatrick (130). Kirkpatrick's framework in the context of trauma training courses would be as follows:-

Level 1: reactions: are self-reported satisfaction with the trauma training course, subjectively evaluated, usually with questionnaires, or interviews post-course.

Level 2: learning: by acquisition of new knowledge in managing trauma patients applying open techniques, objectively evaluated, usually with multiple choice questions and similar approaches, pre/post course. Retention testing also applies (as knowledge decays) – i.e. is the newly acquired knowledge retained weeks/months post course?

Level 3: behaviours: this is about skills – i.e. objectively acquiring the ability to manage procedures/patients better following the course, including non-technical skills. This is evaluated through objective skills assessment, e.g. via simulation modules, or real-life data analysed for skill quality pre/post course. Retention testing applies here too, as skills will decay.

Level 4: results: the translation of better skills in carrying out the procedures and managing these patients better to reduce patient mortality and/or morbidity.

Where data on validity and other criteria for evaluation of training courses were available as a result of this search, these were assessed in terms of the Standards for Educational and Psychological Testing published jointly by American Educational Research Association, the American Psychological Association and the National Council on Measurement in Education (131). A misconception about Kirkpatrick's framework is that these 4 levels can be applied to determine whether a training intervention is useful *after* the program has been developed. Instead Kirkpatrick states that trainers must begin with desired results and then determine what behaviour is needed to accomplish them. Then trainers must determine the attitudes, knowledge, and skills that are necessary to bring about the desired behaviour(s). The final challenge is to present the training program in a way that enables the participants not only to learn what they need to know but also to react favourably to the program.

2.2: Results of Trauma Surgery Training Course Search:

Using the above search criteria 36 citations describing 13 open surgery trauma training courses were identified for surgeons. These are summarized in Table 2.1, with intended course participants, format, duration, available course materials, cost and uniform resource locators (URL's). Table 2.1 also identifies whether the courses have been validated with control groups, showing a benefit from those taking the course versus others, and their Kirkpatrick levels of evidence. The results are reported alphabetically under course description and documentation of course metrics, such as testing pre- and post-training and for retention of skills. Among the 22 courses excluded from this review were four covering orthopaedic, obstetric/gynaecology, or maxillo-facial issues, three endovascular skills courses, including two courses teaching resuscitative endovascular balloon occlusion of the aorta (REBOA) skills for trauma, the Trauma Exposure Course (TEC only offered once, at a single site), Tactical Combat Casualty Care (TCCC, designed for Combat Medics), two courses on pediatric trauma, three for non-physician providers, one on trauma-related mental health issues, and four including emergency department reception, first aid and emergency response for non-clinicians.

2.2.1: Training Efficacy of Open Surgical Technical Skills:

The majority of established courses were given without evidence of efficacy. None of Kirkpatrick's levels of evidence (130) were available for seven of these courses (DSTC, DSTS, EMBIC, EWSC, MOST, STAE, STRT). This is not to say that some form of evaluation for 1-5 day courses (e.g. EWSC courses) does not occur, but that no publication of that evaluation could be found. DSTC, ESTARS, EWSC, and SSET used live tissue (usually porcine) making it surprising that no publication on evaluation of efficacy occurred. For cadaver use, for courses such as ASSET, ATLS, DSTC, EWSC and MOST the need for evidence to support cadaver use is even more compelling, but was not found for DSTC, EWSC and MOST. BTLS, STAE and STRT used no cadaver or live tissue, only simulated models or laboratory exercises. Only one course ATLS, fulfils Kirkpatrick's criteria for Level 4 evidence in showing outcome benefit in educational and organizational management outcome. ATLS and ASSET courses have Level 3 evidence from published studies with performance improvement documented after training compared to pre-training and skill retention duration. The remaining courses only have Level 1-2 evidence obtained through subjective self-evaluation and satisfaction surveys and in some courses pre- and post- testing, although few have any skill retention evaluation. The ATOM course has Level 2 evidence because of the wide proliferation of the course and follow-up publications showing high self-reported and satisfaction surveys and pre-post-course, increase in value to surgical practice and questionnaire evaluation showing maintenance of self-efficacy for trauma management. As shown in Table 2.1 there is a large variation in duration, cost, frequency of administration (regular scheduling of courses is necessary to have adequate sites for training and for future skill retention testing). Many of the courses share common trauma procedural core competency ingredients. The American College of Surgeons and Association of Program Directors in Surgery (ACS/APDS) reviewed Technical Skills Assessment Tools and found 23 assessment tools for 35 ACS/APDS core competency skills. Two tools, OSATS and Objective Structured Assessment of Technical Skills (OPRS) have been tested in more than one procedure. Thirty of the ACS/APDS modules had at least 1 assessment tool with some common surgical procedures being addressed by several tools, while 5 modules had no tools applied. The traditional conception of validity divides it into three separate and substitutable types: content, criterion, and construct validities. A new unified concept of convergent validity proposed by Messick (132) considers all aspects of a more comprehensive theory that addresses the score's meaning and social values of tests used their content, substantive, structural, generalizability, external, and consequential aspects of construct validity. In effect, these six aspects function as general validity criteria or standards for all educational and psychological measurement, including performance assessments. Only 3 studies used Messick's framework (132) of convergent validity to design their validity studies. The conclusion was that competency-based training requires better assessment tool validation.

Table 2.1: An alphabetized (by acronym name) of 13 Surgical Skills Training Courses, their intended trainees, duration, cost, frequency of offering, accompanying educational material, reference, whether skill retention was tested, summary with list of Kirkpatrick's Level 1- 4 evidence and evaluation metrics used. Abbreviations used in the Table are defined in the text. NA = not available.

Course Name	Intended Trainees	Duration & Cost	Course Format	Frequency Courses: Lectures:	Course Manual or DVD	URL or Ref	Pre Post Retention	Kirkpatrick's Highest Evidence Level 1-4 Control Group Yes/No	Evaluation Metrics Used to Demonstrate benefit; # studies, End-point for evaluations
ASSET	Surgical residents, fellows and attendings	1 day $500	Unpreserved human cadavers	No Lectures Monthly Courses in 15 US locations	Yes	https://www.facs.org/quality%20programs/trauma/education/asset	All	Level 3. Control Yes : Expert& Practicing surgeon controls	IPS; GRS: Errors. Vascular control; 4 compartment LE fasciotomy
ATLS	Physicians (primarily), nurses and	2 to 2.5 days $ 750	Part Task Trainers and simulated patients (Human	Yes Lectures Monthly Courses in 15 -	Yes	https://www.facs.org/quality%20programs/trauma/atl			Written test score, evaluator ratings, Following

	allied health providers		cadavers and animals in selected locations)	20 US locations		s	All	Level 3- 4 Yes : some studies with controls	decision support algorithms
ATOM	Surgeons	1 day $ 1,750	Live bleeding porcine models	Yes 26 Sites	Yes	http://atomcourse.com	Pre-Post tests & retention	Level 2. No controls	4 papers
BTLS	Surgeons / Nurses/ Technicians	1 day $ NA	Moulage, Simulation Models	Yes. 6 courses/yr. in Sweden	Yes	*J R Army Med Corps 2000;* **146:** *110-114*	No	1 No Controls	No metrics 1 Paper
CACHIRMEX or Adv(ACDS	Surgeons in France. Compulsory for junior military surgeons	3 days (110 hours) $ NA	Human cadavers and live tissue (pigs)	Yes Annual Course	Yes- 5 course modules	J R Army Med Corps 2015: doi:10.1136/jramc	No	1 No Controls	2 Papers
DSTC	Advanced surgical trainees	2 days $ 3,445	Human cadavers and live tissue	Yes. 38 courses in 20 countries in 2014	Yes and slides	http://www.iatsic.org/DSTC.html	No	0	1 Website No metrics
DSTS	Advanced surgical trainees	2 days £1295	Demonstration on anatomical surgical prosections.	Yes	Yes	www.rcseng.ac.uk/coursearch/dsts.html	No	0	1 paper (Trauma. 4:184-188 2002
EWSC	DoD trauma	3 to 5 days	Human cadavers	Yes	Yes	http://www.med.n			War

military service specific variations	surgeons	$ NA	and animal models			avy.mil/sites/nmotc/ Pages/EmergencyWarSurgeryCourse.aspx	No	1 No Controls	Surgery Handbook Describes Course
ISCP Military Specific WBA	Military Surgeon	ISCP general surgery £ 0	WBA of index trauma procedures in real patients. No additional charge	Yes. During Training	Yes	J R Army Med Corps 2015; 161: 100-105	No	2 Surgeon is own control	Workplace Assessment (WBA) Included in Surgery training
SSET	Junior surgical trainees with an interest in general surgery	2 days $ NA	Porcine specimens	Yes	No	https://www.rcseng.ac.uk/courses/couresearch/	No	1 Anecdotal Report No Controls	No formal assessment. Certificate given On completion
STAE	Pre-deployment course for surgeons with an interest in humanitarian & disaster medicine	5 days £ 2,000	Modules and case-based laboratory setting scenarios	Yes Frequency of course offering NA	No	www.rcseng.ac.uk/courses/course-search/surgical-training-for-austere-environments	No	1 No Controls	No Metrics no end-points found
STRT	Surgeons or those deployed to disasters	5 days $NA	Didactic lectures and hands on laboratory	Yes	Yes-Emergency War	http://www.dimo.af.mil/shared/media/document/AFD	No	1	No Metrics no end-points

			exercises		Surgery Handbook	-110720-026.pdf		No Controls	found
Trauma Surgery Course (Italy)	General Surgeons or General and Emergency surgeons	2 days € 1200	Lectures and Live Tissue (porcine)	Yes Course twice per year: 18 participants	Slides and Video	W J Emerg Surg 2006; 1: 5 Doi:10.1186	Pre- Post Testing. No retention	2 No Controls	Metrics demo benefit. Pass/Fail test on 3 scores. Certificate

2.2: Summary of Kirkpatrick Evidence:

The overall quality of validation of the courses shown in Table 2.1 is not strong. Most of the courses have rather superficial evidence of benefit (i.e. levels 1 and 2) in which participant self-evaluations are the only source of information, and small numbers of respondents with very few showing support with longitudinal data before and after training; some more well developed courses (e.g. ATLS, ASSET) have better evidence including level 3, and the ultimate level 4 evidence for ATLS is debatable (e.g. see variable impact of ATLS on management and organizational skills). The supporting evidence is shown in the summary efficacy across the selected courses in Table 2.1, in which the evidence base is systematically abstracted to support each one of the 4 Levels above for each one of the courses. The more detailed descriptions of each course are given below.

2.3.1: Advanced Surgical Skills for Exposure in Trauma (ASSET):

The ASSET course was described in Chapter 1. The course includes an illustrated manual and Digital Video Disc (DVD) containing narrated videos of the major exposures taught in the course, allowing for future review and skills refreshment (51, 64).

2.3.1.1: Training Efficacy of ASSET:

Besides the previously described self-assessed comfort levels in the first 25 ASSET courses, in a second study, seventy-nine surgeons who participated in one of the four beta test ASSET courses were surveyed (133, 134). Self-assessed confidence improved in all body regions ($p < 0.001$), with the greatest increase in upper extremity and chest. Pre- and post-course self-report scores correlated with trauma operative experience. Pre-course self-reported scores differed by level of training. Instructor evaluations correlated with previous experience on a trauma service. The study concluded that ASSET adds new surgical skills and improves participant self-assessed ability to perform emergent surgical exposure of vital structures (64). In a third study of ASSET training efficacy, an interim analysis, studies focused on validating the ASSET curriculum used non-technical and technical skill assessments for 4 representative procedures taught in the ASSET course (3 vascular exposures plus lower extremity fasciotomy). The performance of 12 surgical residents was evaluated before and after training using an individual procedure score (IPS) and global ratings in a comprehensive Trauma Readiness Index (TRI) performance metric (135). Correctly performed specific procedural steps increased 21%, technical skills increased 12%, and overall TRI from 50% to 64% with ASSET Training.

2.3.1.2: IPS Metric Validation:

In a fourth study of training benefit of ASSET, the IPS metric was validated with 40 surgical residents and fellows performing the same four procedures before and within two weeks after ASSET training (136, 137). All evaluation scores increased and time shortened for each of the three artery exposures evaluated after training. Self-reported confidence improved. Procedure steps performed correctly increased 57%, anatomic knowledge increased 43%, and time from skin incision to passage of a vessel loop twice around the correct vessel decreased by a mean of 2.5 minutes. Overall readiness, judged by a comprehensive Trauma Readiness Index (TRI) vascular score for the three representative vascular exposure procedures, increased 28% with ASSET Training. It was concluded that improved knowledge of surface landmarks and underlying anatomy is associated with increased IPS, faster procedures, and more accurate incision placement and successful vascular control. Structural recognition during specific procedural steps and anatomic knowledge were identified as key points learned during the ASSET course (137). The duration of ASSET course training skill-retention has been reported in abstracts accepted for ACS Clinical Congress (October 2016 presentation and paper submission). In a longitudinal study, 38 of 40 previously evaluated surgeons showed no skills degradation up to 18 months after training. Interval experience, not time since training determined performance using the IPS metric.

2.3.2: Advanced Trauma Life Support System (ATLS):

ATLS is the internationally recognized trauma training course, developed and administered by the American College of Surgeons Committee on Trauma to teach a safe and reliable approach to the initial management of trauma patients for all physicians involved in their care. The ATLS course is currently taught in over 65 countries and more than a million participants have completed the course. ATLS focuses on the initial emergency department management of the traumatically injured patient and consists of lectures, demonstrations, and discussions of initial assessments and resuscitation designed around case-based scenarios. Skill stations are taught using part-task trainers, moulaged standardized patient actors and human patient simulators. Cadavers or animal models can be used depending on the site. The ATLS manual is now in its ninth edition (138). The ATLS curriculum is updated every four years; changes to the last two editions have only been made when supported by evidence.

2.3.2.1: Training Efficacy of ATLS:

A 2014 systematic review (139) found there is level 1 evidence that ATLS significantly improves the knowledge base, clinical skills, organization, and ability to prioritize of participants managing multiple trauma patients. Support for ATLS training influence on outcomes in the literature is mostly descriptive. The Cochrane Database Systematic Review published in 2014 (139) found there is no evidence from controlled trials that training of trauma clinicians with ATLS or similar programs impact the outcome for victims of injury, although there is evidence that educational initiatives improve hospital staff knowledge of available emergency interventions. Furthermore, there is no clinical evidence that incorporating ATLS training into trauma management systems positively impacts outcomes. The review recommended that future research should concentrate on evaluation of trauma systems incorporating ATLS, both within hospitals and at the health system level, by using more rigorous research designs (140). Many believe that ATLS teaching is effective, but ATLS teaches incorrect management and techniques.

2.3.2.2: Evidence of Educational Benefit:

Evidence endorsing the educational benefits of ATLS (141-144) includes a randomized control trial of physicians educated in small group skills stations who performed better than those attending didactic lectures. A comparison of old versus new ATLS (new ATLS incorporated two mandatory interactive lectures and two focused discussion groups) using multiple choice questions (MCQ) showed that the new course content improved clinical trauma management skills and that these skills were maintained for two years. In four studies(141-143, 145) , Ali et al, showed that an objective structured clinical examination (OSCE) and MCQ testing assessing 40 senior medical students (20 ATLS and 20 non-ATLS) demonstrated trauma management skills acquisition by senior medical students after the ATLS course. Similarly, in 32 practicing physicians who applied for an ATLS program in Trinidad and Tobago, study data supported the teaching effectiveness of the ATLS program among practicing physicians. Participants' OSCE scores and cognitive performance in MCQ examinations improved, as did their adherence to trauma priorities, and ability to maintain an organized approach to trauma care. The interaction of multiple factors, including resource constraints, staffing and existing management and trauma training revealed that the effects of ATLS vary in different countries (144) and by trauma deaths (146). ATLS-trained medical staff attained a higher number of defined key treatment objectives and were more effective in their management of the simulated trauma victims than those who had not had this training (146).

2.3.2.3: Skill Retention following ATLS:

Level 1-3 evidence has been reported suggesting that knowledge and skills gained through ATLS participation decline after 6 months, with a maximum decline after 2 years. Organization and prioritization skills, however, are maintained for up to 8 years following ATLS. Skill retention of ATLS training was assessed in 60 practicing physicians by comparative assessment of cognitive skills with MCQ testing pre-ATLS, immediately post-ATLS, at 6 months (group A), 2 years (group B), 4 years (group C), and 6 years (group D) after the course. Trauma management skills were also compared using eight OSCE trauma stations completed by the four groups of physicians. Whereas cognitive and trauma management skills declined after ATLS, these skills were maintained at similar levels between 4 and 6 years after ATLS. Within 6 months of training, failure rates for the MCQ exam were 50%: maximum attrition of cognitive skills occurred within 2 years of ATLS completion. The knowledge decline in nonsurgical trainees was more rapid than surgeons. High patient volume (50 trauma patients/year) maintained higher cognitive knowledge and clinical performance (142, 143). Major principles of adherence to priorities and maintenance of an organized approach to trauma care are preserved for at least 6 years after ATLS and ATLS has been credited with improving knowledge, organization, and procedural skills in care of the injured and reducing mortality and morbidity in trauma systems (144, 147).

2.3.3: Advanced Trauma Operative Management (ATOM):

This one-day course uses a standardized, live porcine model to teach the surgical repair of penetrating traumatic injuries. The components of the course include bleeding from the inferior vena cava (IVC) and the heart that must be managed correctly for survival (148). Additional injury patterns require surgical repair or damage control techniques. ATOM is currently offered in over 26 sites, including in the United States, Canada, Japan, and various sites in Africa, the Middle East, and South America (68). Four publications support the efficacy of ATM, one included a 7-item survey of value to surgical practice. There was a significant increase in pre- to post- ATOM course scores from 3.88 to 4.57 with a follow-up mean score of 4.47 indicating maintenance of benefit.

2.3.4: Training Efficacy of ATOM:

The impact of decreasing faculty-student ratios in the ATOM course from 1:1 to 1:2 was assessed. The 2-student model was rated as excellent by 50-75% of students and 12-44% (depending on the procedure) rated it as good. All four faculty rated all 13 procedures in the two-student model as good to excellent (68) . In 24 surgical residents, self-efficacy scores and multiple choice question (MCQ) examination for ATOM were compared with separate evaluation by seven ATOM instructors. Both residents and instructors rated ATOM according to a 10-item, 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). All faculty and residents rated the following items as 4-5: objectives were met; knowledge, skills, clinical training, judgment and confidence improved; the live animal is a useful representation of clinical trauma. Self-efficacy, trauma knowledge and skills improved significantly with ATOM training. Preference was expressed for the live animal versus cadaver model (68, 149).

2.3.5: Battlefield Advanced Trauma Life Support (BATLS):

BATLS is a one-day course developed by the Royal Army Medical Corps (150) to train military personnel in the management of severe but potentially survivable injury whose favourable outcome is affected by timely application of trauma care. The one-day course is designed for physicians, nurses and medical technicians; the course teaches primary, secondary and definitive trauma care, emphasizing the implementation in austere and potentially hostile environments with limited equipment and diagnostic aids. BATLS teaches that haemorrhage must be arrested, if possible, and the circulating volume restored to an acceptable level for casualties with compressible haemorrhage, whereas uncontrollable (non-compressible) haemorrhage requires urgent surgical intervention. Records from all Swedish BATLS courses during 1998-2007 show 61 courses offered with a total of 1254 students (295 physicians, 764 nurses, 176 medical orderlies and 19 belonging to other categories) (151).

2.3.6: Training Efficacy of BATLS:

Over time BATLS has become a pre-mission deployment course. When the British BATLS concept was introduced in Sweden, the general level of trauma training among medical personnel was inadequate for the wartime needs of the Armed Forces. Today, the courses aim to improve tactical medical skills relevant to the environment in which they will serve (151). No objective evaluation of training benefit was found in the literature.

2.3.7: Cours Avancé de Chirurgie en Mission Extérieure (CACHIRMEX):

CACHIRMEX is a three-day War Surgery Course developed in 2007, conducted annually at the École du Val-de-Grâce in Paris and is part of the required curriculum for military surgeons in France (152, 153). It contains 5 modules and a total of 110 hours of training. The course modules include: overview of war surgery; didactic lectures, deployment experience reports, and hands-on management of extremity and soft tissue injuries; head, neck, spine and thoracic injuries; abdomen and pelvis injuries; and severe bleeding. Human cadavers and live tissue (swine) are used, providing exposure to a wide range of skills required of the military surgeon (153). A recent publication provides more detail of the course, but no metrics (J R Army Med Corps 2015 Oct 13th doi:10.1136/jramc)

2.3.8: Definitive Surgical Trauma Care (DSTC) Course:

DSTC was developed by the International Association for Trauma and Surgical Intensive Care under the auspices of the International Surgical Society. DSTC teaches surgeons and advanced surgical trainees strategic thinking and decision-making in the management of severely injured patients and practical surgical skills to manage major organ injuries (154). DSTC is an intensive 2-day course comprising lectures, interactive case discussions and laboratory-based surgical skills training. The surgical skills laboratory is variably comprised of cadaver, live- animal, or both animal and cadaver (fixed or fresh) models depending on the local availability and cultural sensitivities regarding use of such models. In 2014, 38 courses were taught in more than 20 countries.

2.3.9: Definitive Surgical Trauma Skills (DSTS) Course:

DSTS was developed as collaborative effort between the Royal College of Surgeons of England (RCSE), the United Kingdom (UK) Defence Medical Services and the Uniformed Services University of the Health Sciences in the United States (154). The premise was that surgeons in the UK have limited experience with the management of traumatic injuries and that confidence to manage trauma could be improved with a structured curriculum. There is significant content overlap with the DSTC course, but the emphasis is on cardiothoracic injuries and vascular surgical techniques. The course emphasizes the concepts of damage control surgical techniques and resuscitation using limited didactic material and 2 days in the human cadaver laboratory with a scenario-driven approach. The curriculum includes liver packing, vascular shunting and repair, and techniques to deal with and repair injuries to the heart, great vessels, and structures within the abdomen (154), (155).

2.3.10: The Emergency Management of Battlefield Injuries Course (EMBIC):

EMBIC is conducted by the North Atlantic Treaty Organization (NATO) Centre of Excellence for Military Medicine in Budapest, Hungary and was developed in cooperation with the French École du Val-de-Grâce. This is a five day team course that includes hands on workshops for airway management, haemorrhage control procedures, emergent invasive procedures, Focused

Assessment with Sonography for Trauma (FAST) scan, clamshell thoracotomy, decompressive craniotomy, and limb external fixation (155). Little information is available on this course and it is not included in Table 2.1 for this reason.

2.3.11: Emergency War Surgery Course (EWSC):

The 3-day EWSC establishes combat trauma training competencies and coordinates training to develop and sustain U.S. Department of Defense (DoD) trauma surgical skills whether located in an operational environment, Military Treatment Facility or at a military trauma center. First conducted in 1996, this course has undergone multiple revisions and is currently designed to prepare surgeons who are being combat-deployed to manage combat specific wounds. The course provides exposure to current Joint Trauma System Clinical Practice Guidelines. The course includes both animal and human cadaver hands-on laboratory experiences and didactic lectures on war wounds, battlefield trauma systems, shock and resuscitation, and field critical care. Surgical skills are taught for face, neck, and ocular injuries, head injuries, damage control concepts and principles, abdominal, thoracic, soft tissue injury management, extremity fracture management, axial fracture management, compartment syndrome and peripheral vascular injuries (155).

2.3.12: Military Operational Surgical Training (MOST):

MOST was developed by the UK military to deliver whole-team surgical trauma training [29]. The course was created and modified from a number of existing courses to include the DSTS™ course, a mangled extremities workshop, a neurosurgery workshop, and a maxillo-facial workshop. In addition, MOST provides simulation training in damage control surgery principles and resuscitative techniques used to save life and limb. MOST course faculty have recent operational experience and the course is continuously updated to reflect current operational concerns and lessons learned**.** The MOST course aims to break down traditional boundaries between disciplines, giving integrated training where patient care, team capabilities and outcomes remain the focus. General, orthopaedic and plastic surgeons train alongside anaesthesiologists, emergency physicians, operating theatre nurses and technicians, to deliver optimal resuscitation, operative and post-operative care. The course includes a live link to a deployed surgical team and is mandatory for deploying UK surgical teams. Deployable surgeons must take a refresher course every three years (156).

2.3.13: Specialty Skills in Emergency Surgery and Trauma (SSET) Course:

This two-day course aims to help junior trainees in general surgery develop theoretical and practical skills in emergency and trauma surgery. The interactive course uses two students per porcine specimen. The two-day curriculum includes a mixture of small group discussions, lectures, and hands-on practical sessions. Day 1 practical sessions include an introduction to emergency surgery covering exploratory laparotomy, open appendectomy, embolectomy, and vascular patch repair. Day 2 focuses on haemorrhage control, packing the abdomen, and hepatic and splenic trauma, as well as emergency thoracotomy and management of intrathoracic haemorrhage. Each day ends with a small group session covering professionalism and legal issues that surround emergency surgery. During the SSET course, continuous informal feedback is given to participants, but there is no formal assessment. A certificate is given on completion of the course.

2.3.13.1: Training Efficacy of SSET

One anecdotal recommendation for this course, the only published support found, (http://careers.bmj.com/careers/advice/view-article.html?id=20010342) stated that it provides an excellent opportunity to get hands-on practice in emergency surgery skills with a very experienced and enthusiastic team of tutors, high tutor-to-student ratio (1:2) during practical sessions, and the small-group case-based discussion for common emergency surgical techniques.

2.3.14: Surgical Training for Austere Environments (STAE) Course:

The STAE Course was developed as a pre-deployment course for surgeons with an interest in humanitarian and disaster medicine. This five-day course held at RCSE includes content from both the DSTS and MOST courses with additional emphasise on skills needed in for humanitarian and disaster care. The course includes modules on the management of penetrating and crush injuries as well as the management of trauma of the limbs, head, thorax, and torso. Additional modules cover neurosurgery, obstetrics and Caesarean section, advanced wound closure techniques, and orthopaedic trauma. (155)

2.3.15: Surgical Trauma Response Techniques (STRT) Course:

STRT combines lectures and "hands-on" laboratory exercises to refresh and improve surgical trauma response techniques in emergency wartime situations using lessons learned from forward surgical hospitals in a 5-day course. The goal of the STRT course, conducted by the U.S. Air Force and Navy Defense Institute for Medical Operations, is to teach and refresh advanced surgical trauma response techniques relevant to an emergency wartime situation, including state-of-the-art principles and practices of forward trauma surgery. Lecture topics include vascular trauma and damage control surgery concepts. The laboratory exercises cover extremity, head and eye, liver salvage, and truncal trauma. Each participant is provided with a copy of the Emergency War Surgery Handbook.

2.3.16: The Trauma Surgery Course (Bologna, Italy):

A two-day trauma surgery course was developed in 2002 and is offered twice a year in Bologna Italy aimed at the general and emergency surgeon. The first seven courses enrolled 126 participants with Day 1 being didactic material and case-based scenarios. On Day 2 the participants performed common trauma procedure on anesthetized swine. Evaluations included technical and non-technical skills including three different scores for abdominal, thoracic and emergency surgery technical skills an overall course evaluation and a certificate of completion. No participants received an insufficient score (not identified), although the course could be repeated free of charge if a candidate "failed". The authors suggested that this course should be integrated into Italian surgery training programs

2.4: Evidence for the Efficacy of Trauma Training:

At present, no published evidence from controlled trials exists suggesting that surgical skills training courses change trauma patient outcome or improve performance of the skills taught in the real-world operating room (140, 157) fulfilling Kirkpatrick's Level IV criteria. Such studies are needed, but would be confounded by the effects of team versus individual surgeon performance on patient outcome and the need to exclude the influence of non-technical factors on surgeon technical skill (158). Future research designs should include technical and non-technical skill performance metrics, study designs that include Messick's framework for validation (132), and include evaluation before and after training as well as follow-up to determine when and how skill degradation occurs. The latter is particularly important in that research efforts to study surgical skill degradation over time are a high priority, and skills training is relatively easy, but the effort and cost of skills maintenance is significant.

2.4.1: Evidence for Training Benefit:

Level 1-2 evidence shows that knowledge and skills gained through ATLS participation decline at varying rates after 6 months (142, 159). Of the various elements of ATLS, organization and priority skills may persist for up to 8 years (157), so these may be the most useful facets of ATLS for practicing trauma surgeons. Similar to airline pilots (160), ATLS knowledge and skills assessments may become necessary every 6 months. Strong evidence showing that ATLS training reduces morbidity and mortality in trauma patients is still lacking (157, 159), although some studies suggest that mortality outcome may depend on the country in which ATLS is implemented (143).

2.4.2: Challenges in Assessing Benefits of Surgical Skills Training:

A major challenge in assessing the impact of trauma surgical skills training courses is a lack of trauma surgery performance measures; such measures are needed to study outcomes after trauma skills training (136, 161-163). A further difficulty is the lack of standardization of training course material and disparities in training conditions (e.g. length and content of courses) and inclusion of different levels of trainees in the courses (155, 162-164). In currently reported studies examining trauma skill training courses, few courses report evaluations of senior attending or consultant surgeons participating as trainees; such participation would appear to be beneficial, given the low incidence in civilian practice of the injuries taught in these courses,

2.4.3: Maintenance of Skills after Training:

Study of the ATLS course showed the maintenance of technical skills over 2 years (143, 163), other surgical skills courses have not been studied to provide evidence that skills acquired in training courses are retained over years. While there is some evidence relating to skill retention for other types of surgical training, such evidence is still lacking for trauma skill courses. In a randomized trial, the optimal frequency of training for medical students in endoscopic suturing was comparable between weekly and daily practice. Optional deliberate suturing practice reduced skill decay at 6 months after training (165). Simulator training has been shown to improve resident performance of basic surgical tasks such as suturing in the operating room. However, no metrics applicable to open surgery training, assess the entirety of technical skills employed by expert surgeons in the operating room (166-168) and across different procedures performed by the same surgeon (70, 163, 164) . There is some preliminary evidence that hand-motion analysis may be useful to document surgical training and provide objective measure of skill retention (169).

2.4.4: Battlefield Surgery:

In battlefield surgery, the types of surgical cases and the state of preparedness of the deployed surgeons has been documented and include suggestions for improving pre-deployment training (170-172). The DoD in the Defense Health Board (DHB) report of March 9, 2015, "Combat Trauma Lessons Learned for Military Operations of 2001-2013", states: "The lack of comprehensive, standardized training for military health care providers creates an operational gap that affects unit-level training as well as effective utilization of the military system to reduce combat mortality". The DHB suggested that ATOM and ASSET could be augmented to incorporate combat-casualty care- specific training, and also recommended the DoD develop a surgical skills course, including war surgery skills (172). The San Antonio Military Medical Center in conjunction with the US Army Institute of Surgical Research began teaching a 5-day modified EWSC course, including content from both ATOM and ASSET in 2010, called the Joint Forces Combat Trauma Management Course, but no publication of validation of the course has occurred.

The variability of the courses described in this review, the lack of post-training course testing, and the failure to validate with Level 2 or 3 evidence the metrics used in courses except ATLS, ASSET and ATOM means, as noted previously that methodological quality of measuring benefits of surgical training are inadequate (163). Performance should be measured pre/post course with objective indicators. A major problem is that a lot of factors do impact performance affecting patient outcome measures (e.g., a shift in the case mix over time, which if unaccounted for statistically can skew the results) and hence typically the impact of skills training on patient outcome is hard to definitely prove. Furthermore, no data currently exists on retention of surgical skills or the effects of aging or other factors such as interval clinical experience that could impact skill degradation in trauma related surgical specialities (164) .

2.5: Limitations of Review:

This review was focused on training courses that contained open trauma surgical procedural skills. Only a small portion of the content of many courses included surgical procedures. This review did not include skills training for nurses, dentists, paramedics and training in aviation and other professions or industries that might include training useful for improving surgical skills.

2.6: Conclusion of Evidence Synthesis on Trauma Skills Training Courses:

A high priority requirement for the future is to validate existing surgical trauma training courses. An essential part of this process is the development of valid trauma surgical performance metrics for assessing the specific competencies of combat and civilian trauma surgery and for measuring the adequacy of training courses. Such metrics will become increasingly important as trauma care evolves towards less surgery and more critical care (173, 174) . Ideally, valid pre-training skills assessments should be available to permit personalized approaches to skills refreshment. Alternative ways to acquire and maintain trauma skills for practicing surgeons should be examined before surgeons attend 1-5 day training courses whose benefits are not validated. Alternatives such as just-in-time training, heads-up" display of instruction, deliberate practice, multi-media or mental rehearsal tools (175) and mobile training platforms should be considered (176). The approach taken in the UK is to incorporate such trauma skills training into junior surgery training and this approach was suggested in Italy, Scandinavia and is the direction competency-based assessments are moving in the US. The next Chapter 3 is a review of systematic reviews of surgeon performance metrics to determine suitable metrics for open trauma surgery.

Chapter 3: Systematic Reviews of Tools for Assessing Surgical Performance.

3.0: Overview of Chapter 3:

There have been multiple recent systematic reviews of surgeon performance. The aim of Chapter 3 is to conduct a review of these systematic reviews of surgeon performance to determine if there is a need to define a trauma surgical skills metric.

3.1: How surgeon competence in open surgical skills can be determined after training is not simple, as there are no standard methods of evaluation of surgical technical performance, no benchmarks to determine competency, nor is there agreement on how such metrics might improve clinical outcomes (70, 171, 177). Many recent reviews have detailed the state of observational tools for assessing surgeon performance for open surgical procedures, assessing competency, technical skills, psychomotor skills, and skills acquisition measurement (72, 162, 178, 179). There have been multiple recent systematic reviews of objective assessment of technical surgical skills (162) and an assessment of skill acquisition and operative competency in vascular surgical training in 2014 (70) and an analysis of available tools assessing surgeons technical skills (34) as well as a systematic reviews of observational tools for assessment of procedural skills in 2011 (72). A systematic review of tools for direct observation and assessment of psychomotor skills in medical trainees was published in 2013 (71) and also in 2013 there was a systematic review of open surgical simulation (58). A further systematic review was considered unnecessary at this time, but a review of reviews was considered to be constructive to inform the development of metrics for this Thesis. The purpose of this narrative review is to summarize the scope of existing systematic reviews of the literature on surgical performance for trauma, to identify whether a trauma-specific surgical performance metric might be necessary and to inform the Thesis studies. Such a summary of what has already been identified by existing systematic reviews is necessary as there are still large capability gaps for measurement of technical skills during performance of trauma core procedures in surgeon's preparing for military deployment. In addition in 2014 only half the number of vascular exposures were completed during US surgeon's residency training in comparison to the numbers performed 10 years earlier.

3.2: Search Methods for Review of Systematic Reviews:

Structured searches of PubMed were conducted from 1980 to present to identify systematic reviews on tools to measure surgical skills in vascular or trauma surgery using three concepts: (i) clinical skills, including clinical competence and psychomotor performance; (ii) measurement tools, including educational measurement, psychometrics, tool, and instrument; (iii) surgery, including vascular surgery and trauma surgery. The search incorporated both subject headings and text words. After applying PubMed's systematic review filter, and limiting results to those in English and published since 1980, 286 citations were found. Additional articles on surgical performance were identified using Google Scholar and Ebsco's Discovery Service, a tool that searches 50 databases as well as the University of Maryland's Health Sciences and Human Services Library's catalogue. A PRISMA diagram (Fig 3.1 below) describes on what basis the final reviews were selected. Performance metrics for trauma surgery were assessed using principles of validity, reliability and fairness (for measurement of knowledge, skills and abilities) as identified by Standards for Educational and Psychological Testing published jointly by American Educational Research Association, the American Psychological Association and the National Council on Measurement in Education(131).

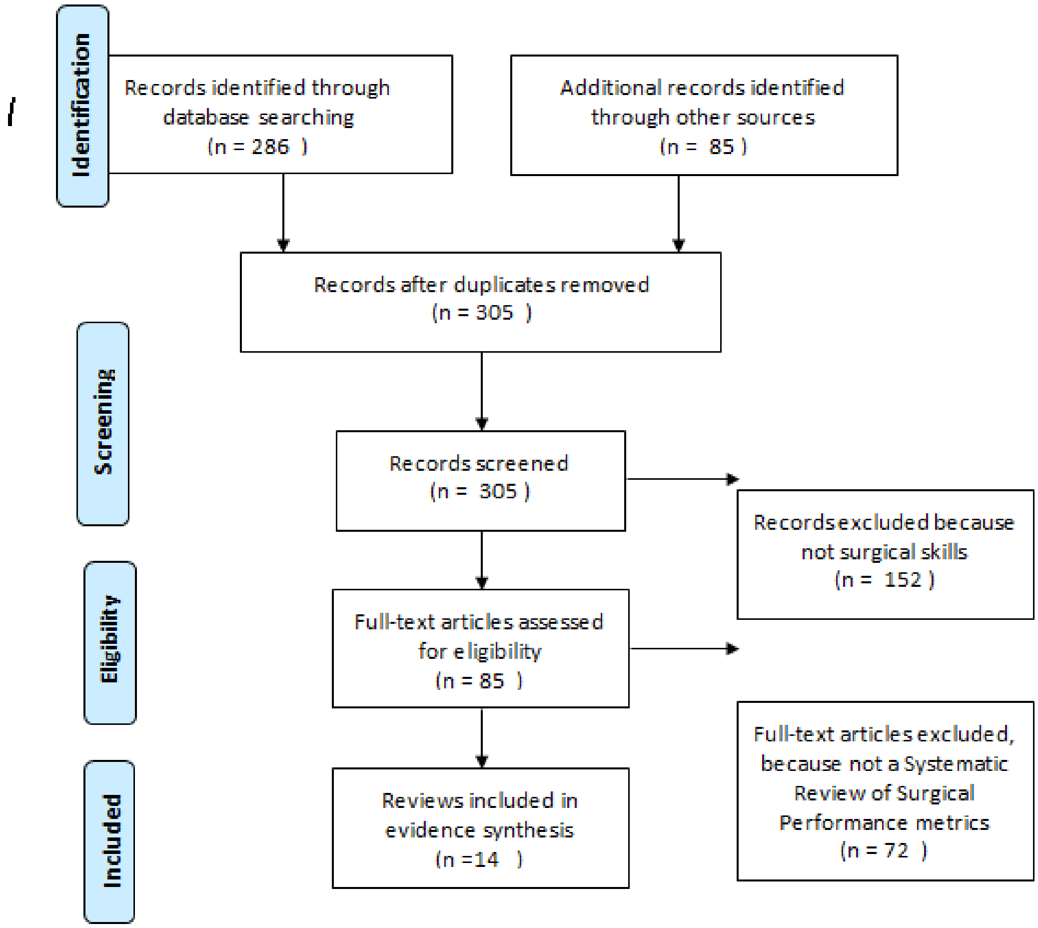
3.2.1: Inclusion Criteria:

Systematic Reviews were included if they described individual surgeon performance metrics for assessing open surgical procedures specific to trauma or general surgical or vascular surgical procedures relevant to trauma management such as acute thoracic, abdominal, pelvic and extremity procedures.

3.2.2: Exclusion Criteria:

Systematic Reviews that addressed team performance skills, elective surgery for gynaecological, ophthalmological, neurosurgical, and other surgical procedures, surgical outcomes of trauma procedures and all Systematic Reviews examining non-technical skills alone were excluded.

Figure 3.1 : PRISMA Flow Diagram



3.2.3: Data Extraction from Systematic Reviews:

Information extracted from the retrieved systematic review articles was entered into a structured data extraction format to ensure consistency in obtaining material relevant to the review, including validity, reliability, feasibility, association with skill being evaluated, limitations of review, number of studies included, number of tools described and studies per tool (where available) and whether tools described included Global Rating Scales (GRS) or checklists(CL) or both GRS and CL . The identified studies were heterogenic ranging from evaluation of skills transfer from bench models to the operating room, studies using cadavers, performance evaluation in simulated operating rooms, to evaluations based on single procedures or component tasks such as knot tying and suturing, allowing limited direct data comparison and statistical pooling of these data. Wherever possible, a critical evaluation was made of groups of studies that applied the same metrics in different domains.

3.3: Results:

3.3.1: Summary of Surgeon Performance Tools Described in Published Systematic Reviews.

Legend for Table 3.1: Summary of Thirteen Systematic Reviews of metrics used to evaluate surgical performance of technical and in some reviews, non-technical skills. The table summarizes the skills evaluated, the conclusions on reliability, validity, feasibility and limitations of the metrics described in the reviews. The Association of the metrics described to the surgical skills evaluated , the number of studies included in each Systematic Review, the number of surgeon performance tools described and number of studies per tool (where available) and whether Global Rating Scores (GRS) and/or Checklist scoring was included in the metrics described. The Systematic Reviews are ordered alphabetically by first author. Abbreviations used in Table : ADEPT = Advanced Dundee Psychomotor Tester; CL= Checklist; FLS = Fundamentals of Laparoscopic Skills; GRS-E = Global Rating Scores +Errors; GRS-MRS = GRS + Modified Reznick Scale; GOALS = Global Operative Assessment of Laparoscopic Skills; ICEPS = Imperial College Evaluation of Procedure – specific Skill; ; ICSAD= Imperial College Surgical Assessment Device ; IPS = Individual Procedure Score; MERSQI = Medical education Research Study Quality Instrument , MISTELS = McGill Inanimate System for Training and Evaluation of Laparoscopic Skills; NOTECHS = Non-Technical Skill Scale; NOTTS= Non-Technical Skills for Surgeons; OSATS= Objective Structured Assessment of Technical Skills; PA= Psychomotor Aptitude; PBA = Procedure Based Assessment; QADAS 2 = Quality Assessment of Diagnostic Accuracy Studies; RCT = Randomized Clinical Trial; SAVE = Structured Assessment of Endovascular Expertise; VSP = Visual Spatial

Citation by 1st author	Skills Evaluated	Validity	Reliability	Feasibility / Limitations	Associations within skills evaluated	Number of Studies included	Number of tools & Studies/tool	Split GRS/ Checklist
Ahmed Am J Surg 2011; 202: 469-480	Technical/multi-speciality surgical procedural skills /anaesthesia	Evidence of validity at Trainee level, but tools not adequate for Specialist Level	Inter-Rater Reliability tested in all tools	Excluded assessment tools to measure only performance	Methodological limitations and evaluator training tools lacking	106 studies included	29 GRS, 30 Task specific checklists 47 combination of GRS and Checklists	GRS and task specific checklists
Arora Surgery 210; 147: 318–330.e6	Performance stress with Laparoscopic, bleeding, time pressure, equipment	Objective data on HR/ECG (8), survey/self-report(8), no measure (4) saliva/skin (4) Time, knot-tying, motion, eye/blinking	Control groups in 6 studies included other medical professions, musicians, pilots	Validated self-report tools not used. Lack combination objective and subjective metrics. Some survey only.	Direct association with skill performance in both real & simulated tasks	22 including general, plastic thoracic, ophthalmological surgeons. Some studies surveys not in OR	Prospective experiments (14) objective metrics; observational (4) not validated interview/survey (3)	Combination objective data self-reports. Stress levels > in laparoscopic than open
Beard Health Tech Assess 2011; 15:1-169	Skills during general, cardio/vascular and orthopaedic surgery, Ob & Gyn	NOTTS had formative value for non-technical and technical skills. PBA and NOTTS had > validity than OSATS to year training and experience	PBA high reliability, OSATS lower on index procedures, mixture of procedures best reliability. NOTTS < PBA	Most surgeons were junior. Response rate for follow-up of surveys sub-optimal	Operative Competence in 6 specialities	2 year prospective study 15 index procedures across 6 surgical specialities	PBA, OSATS, NOTTS Hindsight should have used video-recording more	Both.
Cook Acad Med 2013; 88:872-	Procedural skills minimal invasive (142) & open (81) surgery, endoscopy(67)	Relation to trainee experience, other measures. Only 64% presented validity argument	Inter-rater reliability	Many studies had high risk bias. Methodological quality low in many studies	Simulation based evidence tools by speciality and source of valid evidence	417 studies , 84% included physicians	Messick's 5 source framework, MERSQI and QADAS 2 used for validity, for methods quality and bias	Including: OSATS, MISTELS, VIST, ICSAD LapSim, MIST-VR, Lap-Mentor , Eye-SIM

883								
Citation by 1st author	**Skills Evaluated**	**Validity**	**Reliability**	**Feasibility / Limitations**	**Associations within skills evaluated**	**Number of Studies included**	**Number of tools & Studies/tool**	**Split GRS/ Checklist**
Dawe Br J Surg 2104; 101: 1063-1076	Simulated Performance Laparoscopic (14), Endoscopic (13), 7 studies other procedures vs Surgical performance	Overall weak evidence for simulator training benefits on surgeon performance , more so vs no training and when integrated into patient based training	Large variability in methods data collection, outcomes and metrics used, duration and intensity of simulation training	Methodological detail incomplete. Only technical skills assessed. None used NOTECHS or NOTTS	Review supports hypothesis that simulation is better than no training. Evidence for simulation v patient training weak	Randomized trials (27) and 7 non-randomized comparisons	34 % studies reported overall performance parameter	Both, including OSATS, GOALS,MISTELS, VR-Sim but majority used GRS
Ilgen Med Educ 2015; 49: 161-173	Open and Laparoscopic surgery, endoscopy, resuscitation, anaesthetics	Validity Evidence GRS v Checklists	Reliability effects & correlations pooled with random–effects meta-analysis	Each task a separate checklist. GRS has higher inter-station reliability	Checklists reliability and trainee discriminate better than previously thought	45 studies with simultaneous checklists and GRS	MERSQI in all studies & OSATS used in 1/3rd studies	All used both checklists and GRS as systematic review inclusion criteria.
Jelovesek Med Educ 2013; 47: 650-673	Psychometric surgical or procedural skills of trainees	Validity based on associations between scores and training level was identified in 24 tools, internal consistency in 14,	Test-retest reliability in five tools and inter-rater reliability in 20	Evidence supporting psychometric and edumetric properties is limited	7-item GRS & PBA recommended based on Level A ACGME evidence	51 studies	30 tools identified	Both
Kogan JAMA 2009; 302:	Observation of direct patient encounters for performance based-clinical	11 tools validity evidence based on internal structure and relationship to other variables. The strongest validity evidence has been established for the	Trainee or observer attitudes about the tool were the most commonly measured outcomes.	Rater training was described for 26 tools. Operative Technical skills were excluded	validity evidence and description of educational outcomes are scarce	85 studies	55 tools: 21 with students and 32 with residents. 2 used across educational continuum. Most	Both, with scales and anchors

1316-1326	skills	Mini Clinical Evaluation Exercise (Mini-CEX)					(n=32) developed for formative assessment	
Citation by 1st author	**Skills Evaluated**	**Validity**	**Reliability**	**Feasibility / Limitations**	**Associations within skills evaluated**	**Number of Studies included**	**Number of tools & Studies/tool**	**Split GRS/ Checklist**
Mann Br J Surg 2012; 99: 1610-21	Predictive value of attributes for surgical performance	Only qualitative studies found of visual spatial (VSP) & psychomotor aptitude (PA)	Only qualitative studies found	Methodology quality low, bias , lack of valid tools and objective outcomes	VSP predicts ability, skill acquisition & quality of surgical performance. PA predicts rate of skill acquisition.	27 met qualitative synthesis criteria	Gross and fine motor dexterity & time. Written exam performance	Neither used .Faculty Assessment method not described
Maruthappu Br J Surg 2014; 101: 1491-	Methodology of studies investigating individual performance in surgery	48 studies showed learning curve of surgeons, 60/101 had duration and few had surgical outcomes, mortality complications	Understanding of individual surgical performance measurement and assessment remains limited. Better methodology for metrics development required	42%employed statistical modelling or stratification to adjust performance measures. Studied heterogenic populations	Currently employed outcomes and methodology for performance metrics are poor	51·5 % of studies investigated ≤500 procedures. 77/101 single-centre studies.	101 studies of 1 006 037 procedures by 14 455 surgeons. 34studies prospective 66 retrospective.	Not Stated
Maruthappu Ann Surg 2015; 261: 642-647	Surgical experience on performance of 35 different procedures	Increased cases correlated with improved health outcomes. Plateau phase in the surgical learning curve which was procedure specific, outcome specific, ranging from 25 to 750 procedures.	Large number of cases and procedures. Heterogeneity of methodology, metrics and analyses limit the reliability of studies of performance	Examined only case volume procedure, experience , surgeons age no non-technical skills examined	Twelve studies assessed the impact of years of surgical practice. Beyond 20 years skills deteriorate	57 studies	4 outcomes examined across all 57 studies and 4 large databases	Both

Mitchell J Vasc Surg 2014; 59: 1440-55	Skill acquisition vascular surgical competency	CL PBA and GRS all had validity for specific simulated procedures. Lack of generalizability to OR	GRS and PBA had high inter-rater reliability	No tools were found applicable across all vascular procedures & training programs	GRS IPS PBA	48 studies 29 open vascular skills; 19, endovascular skills; 6 nontechnical ,1 teamwork skills	ICEPS (6), SAVE(1), IC 3ST (2), PBA IPS (7), Errors. CL (16) MRS (3) GRS, (20); GRS-E,(7)	Both and their modification GRS-E and CL-MRS
Sturm Ann Surg 2008; 248: 166-179	Simulated surgical skills training transfer to operative setting	All but 1 RCT < 20 subjects. Metrics un-validated. Type 1 errors likely	Small evidence base; different procedures variation in performance metrics used, limit conclusions	Variations in study design, & length of simulator training. Often no baseline data	No simulator derived metric could determine competency on operative setting	11 studies; 10 RCT's and 1 other comparison	Time, errors , surgeon take –over , incompletion	Both

3.4: Overview of Global Rating Scales (GRS):

Global Ratings Scales judge overall performance. GRS may detect differing levels of expertise with more sensitivity than checklists, although GRS are subjective, they depend the rater's understanding of the task, training and the rater personality. GRS are rarely used in high-stakes assessments (133). In a systematic review of validity evidence for GRS versus checklists in simulation based assessments of medical and nursing personnel performing surgical, resuscitation and anaesthesia tasks, Ilgen et al (133) found 43 studies using GRS with an average of 6 items (median:7 range:1-13). The anchors most commonly used for GRS were observable behavioural actions, proficiency (high to low) and Likert-based scale anchors. Studies were focused on "positive metrics" with little exploration of resilience or managing the unexpected. Thirteen studies of surgeons used the OSATS GRS or a slight modification (111). A standard seven parameter GRS (maximum score = 35) is used for the for OSATS GRS consisting of a Likert 1-5 scale evaluating respect for tissue, time and motion, instrument handling, and knowledge of instruments, use of assistants, flow of operation and planning, knowledge of specific procedure. GRS raters were typically physicians, but some studies included nurses and respiratory therapists as raters. Less than half the studies described any training of raters. GRS and a checklist were completed by the same rater in 39/45 studies of which 22 GRS ratings were made in real-time, the remainder by retrospective video review, except one study used both. Nearly all multi-station studies used the same GRS at each station, and this increased reliability of the instrument. Ilgen et al list many shortcomings among the GRS studies including an inability to estimate the direction, magnitude or influence of one rating scale over another. GRS were used in simulations for evaluation of technical tasks, so in their opinion GRS may not be useful to assess cognitive and non-technical task performance. They felt there was insufficient granularity to assess specific technical skills as their systematic review relied on data from previously reported studies, not on the original collected data.

3.5: Overview of Task-Specific Checklists:

Checklists assess performance of specific tasks or actions. Checklists have the benefit of simplicity, but require a binary response, with the potential loss of fidelity in clinical competence that an expert may exhibit. The most commonly used instrument for assessing surgical technical skills is the objective structured assessment of technical skills (OSATS) (111). Based in principle on the Objective Structured Clinical Examination format of standardized tasks assessed using a structured score sheet (111, 134), the OSATS metric is composed of a 17 point step-by-step task specific checklist (maximum score = 17), a seven-item GRS and a pass/fail judgment. Steps between 22 – 32 are assessed for each of six tasks carried out in simulated and live animal surgical procedures. In a paper using OSATS van der Vleuten CPM el al (134) evaluated a variety of tasks including: excision of a skin lesion, hand sewn and stapled bowel anastomosis, insertion of a T-tube, abdominal wall closure and control of inferior vena cava haemorrhage. In the original description of OSATS a simulated model was found to be equivalent to the live model, inter-rater reliability for live and simulated models were similar (0.64- 0.72), correlations between checklists and global ratings were 0.81 and 0.87 respectively and reliability (Cronbach's alpha) was moderate to high except for reliability of the checklist for the simulated models (0.33) and the pass/fail (0.43) (135). One advantage of checklists is their task specificity that can improve the quality of feedback (41, 44)

Table 3.2: Details of Checklists, and Global Ratings Scale (GRS) of Objective Structured Assessment of Technical Skills (IVC = Inferior Vena Cava). Modified from ref (111)).

Item	**Control of Haemorrhage**	**Not Done/Done Incorrectly**	**Done Correctly**
1	Applies pressure to stop bleeding	0	1
2	Asks assistant to suction field	0	1
3	Inspects injury by carefully releasing IVC	0	1
4	Ensures all equipment needed for repair is at hand before starting	0	1
5	Control of bleeding point (deBakey/Satinsky clamp or proximal/ distal pressure)	0	1
	Repair		
6	Select appropriate suture (4.0 -6.0 polypropylene	0	1

7	Select appropriate needle driver (vascular)	0	1
8	Select appropriate forceps (deBakey)	0	1
9	Needle loaded ½- 2/3 from tip 90% time	0	1

Table 3.3: Detailed 5 –point Global Rating Scale (GRS) of Objective Structured Assessment of Technical Skills (Modified from ref (111))

Respect for tissue	1=Frequently used unnecessary force on tissue caused damage by inappropriate use of instruments	2	3= Careful handling of tissue but occasionally caused inadvertent damage	4	5= Consistently handled tissue appropriately with minimum damage
Time and motion	1= Many unnecessary moves	2	3= Efficient time/motion some moves unnecessary	4	5= Economy of movement and maximum efficiency
Instrument handling	1= Repeatedly makes tentative or awkward moves with instruments	2	3=Competent use of instruments, occasionally stiff and awkward	4	5= Fluid moves with instruments and no awkwardness
Knowledge of instruments	1= Frequently asks for the wrong instrument or used an inappropriate instrument	2	3= Knows the names of most instruments, used appropriate instruments for the task	4	5= Obviously familiar with the instruments required and their names
Flow of operation and forward planning	1= Frequently stopped operating or needed to discuss next move	2	3=Demonstrated ability forward planning with steady progression of operative procedure	4	5= Obviously planned course of operation with effortless flow from one move to the next
Knowledge of specific procedure	1= Deficient knowledge. Needed specific	2	3= Know all important aspects of operation	4	5=Demonstrated familiarity with all aspects of operation

	instruction at most operative steps				

3.5.1: Comparison of GRS and Checklists:

The main conclusion of a systematic review of 43 studies, using both GRS and checklists Global Ratings and Checklists for evaluation of simulation-based training was that both have advocates, strengths and weaknesses. Moderate correlations between GRS and checklist scores explained 58% of their variance, inter-rater reliability ratings were similar (133). Checklists were usually generated with expert opinion and inter-rater reliabilities were higher for checklists than GRS in the systematic review (133). The explanations for greater inter-rater reliability provided included i) technical skills may lend themselves better to measurement than less well defined competency, ii) most studies had physician raters who may understand performance targets better, iii) sample size was larger in studies with checklists and iv) there was a heterogeneity of performance, making discrimination easier for raters with check lists. Inter-item reliability of checklists tended to be lower than GRS as checklists assessed multiple domains of competence, checklists used unique task-specific instruments, and many of GRS were used in studies that used the same scale at each station. Both checklists and GRS are used in many performance metrics (e.g. OSATS) and one might assess different or more subtle aspects of the performance than the other.

3.6: Other Performance Metrics:

Many of the other performance metrics described below, contain embedded elements of OSATS. In a review of competency based learning in traumatology (136) medical students (n=67) who received four skills stations lasting a total of 3 hours were compared to a control group of students (n= 127) who received didactic lectures. Both groups were assessed by performance in the summative Objective Structured Clinical Exam (OSCE) 6 months after training. Three OSCE stations tested traumatology psychomotor skills and 5 addressed cognitive skills with checklist scoring. The students trained in the skills stations had significantly ($p < 0.0005$) higher scores in all OSCE stations and the authors suggested this innovation should be incorporated into an undergraduate core curriculum. A study assessing surgical competency, used a bench model of carotid endarterectomy showed that senior trainees were better than junior trainees and received the same scores as practicing consultants. The authors suggest using performance on the bench model for early assessment of trainees to progress to the next stage of training (137). Beard et al (11) have published extensively on setting the standards for summative assessments of operative competence and methods to assess competency and surgical skills in the operating theatre (138). In a more recent and extensive publication they performed a Factor Analysis of OSATS and found that all items designed to reflect the operative process are explained by Factor one . Factor one included (in relative order of importance) technical use of assistants , time-motion-flow and forward planning, knowledge and handling of instruments, relations with patient and surgical team, suturing and knotting skills, respect for tissue (139). They also stress the importance of the metric scores reflecting the intended construct of surgical performance. To be valid, performance scores by each assessment will correlate with each other assessment that measure the same aspect of performance, both within and between instruments. Valid performance scores will increase with duration of surgical training and experience. Higher scores for operative procedures will result in less operative time, blood loss and fewer peri-operative complications and shorter hospital length of stay. A more recent paper describes these outcomes occurring in relation to higher OSATS scores for bariatric surgical procedures (112, 139) also stress the importance of the reliability (precision and discrimination) of the assessment to reflect the reproducibility of the assessment rankings.

3.7: Reviews of Surgical Technical Performance:

Comprehensive systematic reviews of technical surgical procedural skills include those of van Hove et al (140) who found 104 studies of which 20 had a level of evidence of 1b or 2 b and in 28/104 of these studies the assessment of technical surgical skills was made in the operating room. In this critical review and comparison of methods for objective assessment of technical skills, van Hove et al concluded that OSATS is accepted as the ‘gold standard’ but it lacks a high level of evidence to support its use in the operating room for summative assessments. Studies using OSATS in bench simulations with live animals and the operating room found moderate correlation with coefficients that did not exceed 0.8. Blinding of the evaluators to level of training was concluded to be important to avoid unintended bias, as was inclusion of all eligible participants. Based on their review of currently available evidence, most methods of open surgical skills assessment are valid for feedback or measuring progress of training but not for summative assessments and credentialing. Because cut-off values have not been established, they recommend that OSATS should not be used for competency of examination decisions. The issue of cut-off values for the metric developed as a result of this effort are described in Chapter 7 (Figure 7.6). Memon (34) reports that for assessing trainee surgeon's performance and providing feedback, in the United Kingdom and elsewhere, surgical Direct Observation of Procedural Skill (sDOPS) are used, consisting of a checklist covering 10 competencies (www.iscp.ac.uk/Assessment/WBA/Surgical_DOPS.aspx). Performance Based Assessments (PBA) developed by the orthopaedic competency assessment project (OCAP) are also used in the United Kingdom (12, 141). Memon et al (34) suggested that a mixture of assessment tools are needed to define advancement of trainees and re-accreditation of the practicing surgeon.

Ahmed et al (72) found 106 relevant studies with data on technical skills in general surgery, gynaecology, trauma orthopaedics and multiple surgical subspecialties and non-surgical specialties such as anaesthesiology. Studies of medical students, trainees and specialists subjects were included. Among the 106 studies, global ratings scales (GRS) were used in 29, task specific methods in 30 and a combination of GRS and task specific methods in 47. For each study face validity, content and construct validity and reliability were assessed. Since this review was published the concept of validity has changed after the publication of updated definitions, so that not all conclusions remain relevant (142, 143). As regards implementation of any assessments the authors recommend that the metric should be feasible easy and acceptable to study, should have a measured educational impact and be cost-effective as well as predict performance in real-life clinical scenarios. The conclusion of this review was that a combination of global and task-specific assessment tools seems the most comprehensive solution for observational metrics for technical skills.

3.8: Tools to Assess Medical Skills in Live Patients:

Jelovsek et al (144) reported on papers published between 1948-May 2011, to determine which tools assessed psychomotor skills in medical trainees in live patients. After screening 4114 citations to identify psychometric and edumetric properties of tools they found 51 manuscripts that described 30 tools. Twenty four tools showed association between scores and training level, internal consistency was found in 14 tools re-test reliability in 5 and inter–rater reliability in 20. Jelovsek et al in 2013 (144) describe a graded report card evaluation of these 30 tools that allows a user choosing one or a combination of these tools to know the psychometric and edumetric strengths and limitations. A systematic review assessing skill acquisition and operative competency in vascular surgical training (70) found 29 articles evaluating open vascular skills, 19 of which described endovascular skills, six non-technical skills and one teamwork skills. Of these 29 studies, 84% were in simulated environment, 8% in the operating room and 3% in both. No assessment tools were applicable to all study scenarios and procedures. Several of these studies used OSATS and included skills assessments including 611 surgeons and 43 medical students. Less than 19% included evaluations of expert (attending/consultant level) surgeons. Most of the procedures were part-tasks such as knot tying and end-to end/side anastomoses, vein patch angioplasty or sapheno-femoral dissection. Two studies assessed complex vascular exposure (sapheno-femoral dissection, abdominal aortic aneurysm, carotid endarterectomy), one using OSATS checklists, global rating scales procedure based assessment, and a behavioural rating of non-technical skills for surgeons (NOTTS), and the other with oral examination and self-reported confidence levels. Mitchell et al (70) note that an operative assessment tool relevant to vascular/endovascular surgery and generalizable to the wide spectrum of technical and nontechnical skills pertinent to vascular surgery needs to be developed, validated, and implemented to allow the practical assessment of resident readiness to operate in an unsupervised setting.

3.9: Surgical Simulation:

The literature on use of an ATLS checklist of tasks performed before and after a four week trauma center rotation shows that the number of tasks successfully completed were improved by clinical training (145, 146) . Studies using a trauma- mannequin assessed individual trauma assessment scores versus moulage training for interns. Simulator training significantly improved scores (146). In 22 general surgeons, consultants (n = 4), specialist registrars (n =14), and senior house officers (n = 4) performance of a saphenofemoral dissection on patients and the same procedure on an inanimate laboratory model were compared with OSATS. There was a significant relationship between technical skill on the bench test model and the operating theatre performance measured by global rating and checklist ratings. Global rating scores correlated with experience and showed no differences for both operative and bench settings (147). Addition of simulation to conventional surgical training was associated with increased patient comfort and improved staff productivity (148).

3.9.1: Transfer of Simulation Training to Operating Room:

A simulation curriculum of five-sessions that covered asepsis, skin preparation, gowning, gloving, knot-tying, suturing, and excision helped PGY1 residents attain basic surgical skills at levels consistent with PGY2 and PGY3 residents as measured by an OSATS skill station by un-blinded raters, using a task-specific checklist and seven global rating scales only PGY3 residents performed at the 75% criterion (149). However, transfer of the skill benefits curriculum was not tested in the real environment. A systematic review of surgical simulation conducted in the year 2014 found sixteen randomized controlled trials involving 309 participants. Weaknesses were that the studies showed considerable clinical and methodologic diversity. Transfer of skills to the real operating room showed that operative time decreased consistently in all trials after training and duration of surgery was the only objective parameter measurable in the live setting. Studies using OSATS metric as their primary outcome showed improved scores in 80% of trials, but no transfer of skills to the operating room. These studies (150) were deemed insufficient to demonstrate transferability of skills from the laboratory to the operating room (151). On the other hand, three systematic reviews and one meta-analysis confirm that the addition of simulation to conventional surgical training resulted in improved objective performance in the operating room, decreased operating times, increased ability of surgeons to complete the procedure and decreased intra operative rate of errors (152).

3.10: Discussion of What the Scope of the Literature Showed:

Very few objective metrics for evaluation of trauma related vascular exposure and haemorrhage control have been published in the literature. OSATS is the leading metric used to assess surgical competence, but OSATS subjective global ratings do not a measure trauma surgical skills, or competence in emergency haemorrhage control. In addition, the literature is specific in stating that OSATS metrics are inappropriate for summative assessments, because there are no valid cut-off values (140, 150). The evidence for current non-objective, non-documented, unreliable models of assessment is lacking. The systematic reviews of open surgical performance were not useful to inform the Thesis plans as no reviews had trauma as their focus. No metrics have been specifically designed to assess trauma surgical skills even though there are a plethora of trauma surgical skills training courses of variable intensity and duration whose efficacies remain un-validated. In 2003 Wilkinson et al indicated that there were no validated methods of surgical procedural performance assessment in the literature (153). The major findings of this literature review are summarized in Table3.4.

Table 3.4: Examples of deficiencies noted in current reports of surgeon performance:
1) Lack of robust evidence for metrics on feasibility, validity, reliability, acceptability
2) Incomplete descriptions of training of evaluators and calibration of their learning and reliability
3) Lack descriptions of ease of use and interpretation, educational impact and resources required
4) Too few participants in almost all reports; lack of performance assessments of experienced surgeons
5) Metrics describing scales of competence lack testing in both simulated and clinical settings
6) Too few studies of experts, their adaptive strategies and characteristics of surgical excellence
7) Many studies do not have sufficient detail to replicate the study population or content of assessments
8) Evaluator bias, single evaluators, lack of evaluation repetition and blinding of performance evaluations
9) Variability of assessment tools in relation to scale formulation, validity, reliability and

feasibility. Findings should cover associations between different skill sets and surgical procedures.

3.11: What Were the Limitations of This Review?

The search only reported on systematic reviews of surgical performance 1980 to present and some earlier literature may have been missed because the scope of the review was limited to existing systematic reviews of surgical procedural skills. As a result the scope excluded the large body of literature on skills training for nurses, dentists, paramedics and training in aviation and other industries. Paramedics and nurses do perform invasive procedures, but open surgery is a higher level of intervention than the procedures paramedics and nurses routinely perform. However, there may be reports of measures of performance and durability of training within this broader literature body that in principle could be applied to open surgery.

3.12: How Did the Literature Review Inform the Thesis Studies?

There are currently no validated scores for assessing trauma surgical skills for open surgical control of haemorrhage that could be used to demonstrate competence in exposure and control of traumatic vascular haemorrhage or validate existing surgical trauma training courses. Such trauma surgical performance metrics are essential for assessing competency necessary for combat and civilian trauma surgeons and to measure the adequacy of training. There are part-task metrics for suturing, knot-tying and other basic skills often used in "Boot-Camp" courses used for medical students or as an introduction to surgical skills for beginning residents (154). These part-task trainers do not address non-technical skills and overall procedural performance necessary to determine clinical competence. Because of shortened training hours, infrequent exposure to major vascular injury, and the need for just-in-time training prior to deployment, a performance benchmark is needed to confirm that surgeons have the necessary skills. As a result of the background literature reviews of Chapter 2 and 3, I have identified a capability gap in open trauma surgery performance metrics and feel better informed to develop a benchmark performance metric for trauma surgery and to validate this.

Chapter 3 identified the large variety, duration, and resources required to conduct open surgery technical skills courses and lack of evidence for training benefit from surgical skills courses. The systematic review showed no validated surgical performance metrics are available for competence in exposure and control of traumatic vascular haemorrhage the civilian and military surgical community would benefit from standardization of course content, models and duration. A benchmark surgical technical skills performance metric is needed. Chapter 4 describes the plan and methods to develop a surgeon performance metric to validate the one-day ASSET training course.

Chapter 4: Overall Approach to Thesis Design, Methods and Analysis.

4.0: Overview of Chapter 4.

Chapter 4 applies the "lessons learned" from the existing evidence base (as reported in the preceding Chapters) and explains how the procedure-specific metrics were developed with the help of subject-matter experts. Chapter 4 is an overview of key methodological issues, with each subsequent chapter describing specific additional methods for that particular study. The Thesis design and methods for data capture, data analyses and factors that could influence the data interpretation are discussed. The potential biases in data interpretation are identified, the reliability and consistency of evaluator ratings are described.

4.1. Thesis Study Design:

My Thesis has a simple design of before and after a training intervention (the ASSET Course). The process of developing a procedure specific performance metric is shown in Table 4.1 below showing Thesis Study Flow. Aims and Chapters are outlined to show how the Study Plan is related to the Thesis Content. Table 4.1 compared to Table 1.1 amplifies the steps in more detail, to show how the Individual Procedure Score (IPS) metric was developed.

Table 4.1: Table 4.1 is an amplification of Table 1.1 in Chapter 1. Table 4.1 shows how the sequence of the Aims and the two Study Phases flow together. The Chapter notations identify where the topic discussion can be found. ASSET = Advanced Surgical Skills Exposure for Trauma; IPS = Individual Procedure Score

Preliminary Data Collection: PHASE 1

- **Aim 1:** Provide Background to Surgical Training, Haemorrhage Control and Performance for Open Vascular Exposure and control of the extremities: Rationale, Hypotheses and Aims of Thesis (Chapter 1).
- **Aim 2:** Literature reviews of existing trauma skills training and review of existing

surgeon performance metrics (Chapter 2-3).

- **Aim 3:** Develop script for each procedure after Interview expert surgeons and audio-video record "Talk Aloud" during three ASSET open vascular control procedures performed by experts and untrained surgeons. Delphi-like Consensus Conference to modify and finalize script (Chapter 4).
- **Aim 4:** Video Task Analysis to identify defined metrics of procedural steps & landmarks, performance features discriminating experts from novices. Embed Script in mobile Tablet. Train evaluators with video clips and evaluator Handbook (Chapter 4).
- **Aim 5:** Survey Surgeons Self-Reported Confidence training and interval experience in comparison to assessment by trained evaluators (Chapter 5).

Validation Study: PHASE 2; Interim analysis after 12 surgeons enrolled

- **Aim 6:** ASSET novice & expert performance video clips (1-3 minutes) in random (expert/novice) sequence onto Digital Video Disc for inter-rater reliability testing. Interim analysis 12 surgeons to test reliability, consistency and convergence with IPS performance evaluation findings from other metrics, including Global Ratings gathered concurrently (Chapter 6).

Phase 2 Continued: Evaluation Before and After ASSET Course Participation.

- **Aim 7 Continued**: Complete evaluations of all 40 surgeons before and after ASSET Course participation with completion of before and after surgeon self-evaluations. Survey Surgeons training and interval experience (Chapter 7)

Project Assessment after Data Collection Completed:

- Independent statistical analysis; comparison of participant self-assessment, evaluator scores and IPS data, errors and timing before and after ASSET Course training.(Chapter 6 and Chapter 7)
- Correlate quantitative and qualitative data with interval experience (Chapters 6 and 7).
- **Aim 8:** Examine measurement and evaluator bias among evaluations of 40 resident surgeons using blind video review and question item analysis. Compare blind video evaluation results to those of co-located evaluations (Chapter 8).
- **Aim 9:** Summarize Key Findings, Future Studies, Recommendations and Deliverables of

4.2: Development of ASSET Training:

The American College of Surgeons (ACS) Committee on Trauma (COT) leadership established a Surgical Skills Committee in 2005 charged with developing a standardized, skills-based cadaver course. The course was designed to teach surgical exposure of vital structures that are most likely to pose an immediate threat to life or limb when injured. The skills included in the course were culled from a comprehensive list of all possible exposures needed for trauma and a modified Delphi approach was utilized to choose 59 separate skills deemed relevant for inclusion in the course (64). The committee subsequently developed a course manual, narrated videos of selected procedures, faculty manual, laboratory slides, and assessment tools, all of which were subjected to review by subject matter and educational experts. A demonstration course was conducted at the Uniformed Services University of the Health Sciences in March of 2008, followed by three additional beta courses, during which the course was further refined prior to final approval and release of the course as an ACS-branded continuing medical education course in March of 2010 (64). Since that time the course has been widely adopted and there are now over 68 approved sites throughout the US, Canada, Thailand, Norway, Sweden, and UK that have conducted more than 200 courses and trained more than 1500 surgeons.

Fig 4.1: Cover of ASSET Course Booklet. In addition a DVD provides booklet content and video were provided.

4.3: Subject Matter Expert Surgeon Interviews to Develop Procedure-Specific Metrics:

For the three procedures AA, BA, FA exposure and control I was fortunate to have access to three expert trauma surgeons; Sharon Henry, Anne Scalea Professor of Surgery and Attending Surgeon, Shock Trauma Center, University of Maryland School of Medicine. Dr Henry is the ASSET course Director for the Maryland Committee on Trauma. COL (Rtd) Mark Bowyer, Ben Eisman Professor of Surgery, Uniformed Services University of Health Sciences University, Bethesda, Maryland. Dr Bowyer is also the Chair of the American College of Surgeons Committee on Trauma (ASCOT) that developed the ASSET course and Dr Henry was a member of the ACSCOT. Dr Bowyer has taught more ASSET courses all over the world than any other surgeon. COL US Air Force Stacy Shackelford, Attending Surgeon, Shock Trauma Center, Surgeon Commander of US Forces in Afghanistan 2012-2013 and 2016. These three surgeons had between them more than 50 years of experience operating on trauma patients, COL's Bowyer and Shackleford have operated on multiple combat casualties with injuries that the AA, BA, and FA procedure training was designed to teach.

4.3.2: Interview of SME, Comments, Transcription and Review:

After preparation, including review of the anatomy and surgery and management of the three ASSET procedures from surgical textbooks and the ASSET course manual and DVD I became familiar with the AA, BA, FA surgical procedures. I prepared my understanding of the anatomic landmarks, correct skin incision details, procedural steps and correct surgical technique for each procedure. I also prepared questions on common pitfalls and errors made by surgeons-in-training and some questions for the expert surgeons before I interviewed them. As I interviewed the expert trauma surgeons I took notes and transcribed these notes before sending the transcriptions to the surgeons I had interviewed requesting their review, suggestions, comment and revisions (an example of a transcribed interview for a single FA procedure is included as an Appendix I). After I had returned revisions to each expert surgeon, I then re-interviewed each and the notes were again revised to reflect the consensus and correction of any misconceptions. Dr Henry provided expertise on FA (including common, superficial and profunda femoral arteries see Figure4.3), COL Shackelford on AA, and COL Bowyer on BA.

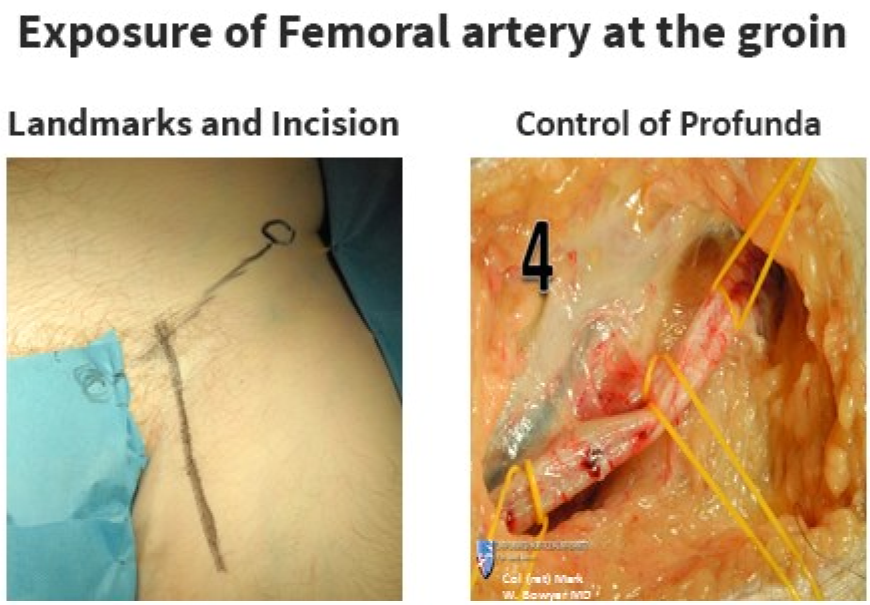


Figure 4.2: *Left Panel: Femoral Artery Landmarks (symphysis pubis and anterior superior iliac spine) and correct skin incision placement (two finger-breadths from symphysis pubis extending 2 cm above line between drawn between symphysis pubis and anterior superior iliac spine; Right Panel: shows exposure of Common, Superficial and Profunda Femoral Arteries with vessel loops placed twice around each artery (surgeons were required to complete double vessel loop placement around all 3 vessels). Photo courtesy Mark Bowyer MD FACS.*

4.4: Pilot Cadaver Data Collection from Expert and ASSET Un-Trained Resident Surgeons to Develop Metrics to Evaluate Vascular Exposure and Control:

Ten expert practicing trauma surgeons with more than 5 years of experience (average 16 years exclusively in Level 1 Trauma Centre practice) were enrolled and requested to perform three procedures, AA , BA and FA exposure and passage of a double vessel loop around the specified vessels. During surgery on unpreserved cadavers, the experts were asked to “Talk Aloud” describing exactly what they were doing and why. In addition, they were asked to describe common pitfalls and errors that they had seen made by surgeons-in-training, when each of the procedures were carried out in trauma patients in real life-threatening circumstances.

After six of the expert surgeons completed the procedures within the first three weeks, it became clear that there was a consistency in the landmarks, skin incision, procedural steps and common errors and pitfalls the experts were describing. Four resident surgeons (PGY 2-4 surgical residents) who had not taken the ASSET course were next requested to perform the three vascular exposure and control procedures. Like the expert surgeons, the resident surgeons were requested to talk out loud and describe the anatomic landmarks, skin incision location and identify anatomic structures as they exposed the vasculature and passed a double vessel loop proximal to the identified injury site. Video clips from the recordings made in these surgeons were used as stimulus material for discussion at the Delphi conference (see below) and later, in preliminary validation of the Individual Procedure Score, for inter-rater reliability testing by blind video review of random expert and novice surgeon performance video clips of the procedures (see below).

4.4.1: Consensus Conference to Agree on Metrics:

To obtain consensus on surgeon performance metrics three conferences were held of experts. The ideas that were include in the reading material given to consensus conference participants included background reading on surgeon performance metric development, existing surgeon performance metrics and some indications of the limitations of the existing metrics and training courses as described in Chapters 1, 2 and 3. The literature reviews included in these Chapters were formulated by me early in the metric development process and provided the background for the other consensus conference participants. We did not use a classic Delphi technique, an iterative process in which anonymous voting occurs and the participants never meet (155). To encourage discussion, besides selected literature, a draft script with embedded metrics was distributed to research team members, for their review before the first consensus meeting. The participants included two experienced practicing consultant trauma surgeons, a non-surgeon trauma clinician/researcher (myself), a research psychologist and two human anatomists both of whom were anatomy demonstrators for medical students. After reviewing video clips of the experts and untrained surgeons performing the AA, BA and FA procedures, the research team members discussed and agreed upon procedure specific technical and non-technical skills performance metrics. Previously described metrics such as OSATS (111), Procedure Based Assessment, (12, 70, 139) and orthopaedic competence evaluation (12) were considered. Video clips from experts and novice surgeons were viewed by the consensus group. The outcome of this first meeting was that surgical technical skills assessment metrics were selected by consensus to best capture the key components of an expert trauma surgeon's performance of these three surgical procedures. Four novice surgical residents were also video recorded and asked to "Talk Aloud" describing exactly what they were doing and why, just as we had asked the experts to do. At the consensus conference the video recordings of both experts and novices were viewed side by side in the conference room. Key steps in each of the procedures identified from the ASSET Course DVD and Course Handbook and Subject Matter Expert surgeon interviews were discussed among the group. One of the Consensus Conference participants, was the Chairman of the American College of Surgeons Committee on Trauma, the original developers of ASSET Training. Features that were thought to differentiate expert from novice performance were identified and included in a script and metrics for each of the three ASSET procedures. The AA, BA and FA scripts are found in Appendix II and each follows a similar pattern. For the second consensus conference, the draft scripts were iteratively modified with input from the evaluators, following this "Piloting" of the script for each of the procedures, we made some minor edits to clarify any ambiguities identified in questions included in the script and the scoring for each of the three procedures. The third consensus meeting was held by tele-conference and discussed the contents of the script used in the case-based scenarios presented in the cadaver laboratory, with an outcome that definitive scripts, with slides were agreed upon.

4.5: Scoring of Metric:

The scoring process was developed based on the consensus conference review of expert commentary made during performance of that procedure (essential responses or actions received

2 points, additional knowledge received 1 point, errors received -2 points if uncorrected and -1 point if recognized and corrected). For each surgeon, scores were calculated in each area of assessment (overall knowledge, anatomic knowledge, patient management knowledge, procedure steps, and technique points) as a percentage of total available points. Time for each procedure was recorded by a start/ stop timer.

4.5.1: Critical Technical, Critical Management and Morbidity Errors:

Errors were classified into 3 levels of severity: critical technique errors (e.g. failed to place the vessel loop around the correct structure); critical management error (e.g. requested a CT angiogram before taking an unstable haemorrhaging patient to the operating room); or non-critical morbidity error (e.g. failed in AA prep to include the groin for possible vein harvest).

4.5.2: Testing Draft Script on Novices:

A further 6 novice surgeons (making total 10 novices) were audio video recorded talking aloud in response to the questions included in the standardized script.

4.6: Process of Evaluation: Script Reading and Performance Scoring.

The final standardized scripts were custom-programmed as a Mobile Application (App) on a touch screen Android Tablet custom App including instructions for both the script reader and the second co-located evaluator and a training mode (see Appendix III for screen graphics). Each enrolled surgeon was given a unique study number. Different sequences of scripts were used (in which the surgical procedures were presented in a different order) to prevent surgeons operating alongside each other hearing their colleagues answers to questions or see them make skin incisions (we had as many as 3 surgeons evaluated together, each at side by side cadaver tables in the same dissection room). The script started with case histories, followed by images of the injuries and then followed by evaluation questions about management, anatomy, treatment, resuscitation, procedural steps and technical operator skills.

The script was read out loud during the evaluations. Questions and instructions were repeated once, if needed, but no prompting or further instruction was provided to the participating surgeons. Anatomic knowledge and procedure steps scores were binary yes/no answers for each knowledge response or step of the procedure, and surgical technique was evaluated on a Likert scale for each of 10 identified technical skills. The IPS metric performance score and TRI are described in Table 4.2

Table 4.2: Derivation of Individual Procedure Score (IPS), Adjusted IPS, Trauma Readiness Index (TRI) and Defines Critical Technical, Critical Management Errors.

Individual Procedure Score (IPS)

- *IPS* $= \dfrac{\text{Checklist* score + time left}}{\text{possible Checklist score + 20'}}$
- *Adjusted IPS* $= \dfrac{\text{Checklist score}}{\text{possible score}}$
  (No Errors or Time)
- *TRI* = Sum of IPS for AA, BA, FA, FAS
- *Errors* = Critical Technical or Management

100-140 items (depending on procedure) in checklist:
7 components of IPS are: Anatomy (Landmarks; Skin Incision; Procedural Steps; Correct Vessel ID)
Knowledge of procedure Management/Indications; Technical Skills
Errors (Critical technical; Critical Management; Morbidity), Error recovery
Time to complete procedure

4.6.1: Training of Evaluators

Evaluators were trained using a custom Training Handbook for the data collection required for this effort (see Appendix IV). Video clips from expert and novice performances were shown as part of the training to illustrate specific components of surgical performance to be evaluated. Evaluators were trained individually, either in person or by video teleconference. The training included use of the Tablet and the scoring system and error designations (errors were either uncorrected or corrected) and of 3 categories (critical technique errors, critical management errors, and non-critical morbidity errors.

Table 4.3: Error Classifications for Each of AA, BA, FA Procedures:

Errors Classifications

Axillary Artery

- Critical Technique Error
  - Fails to loop vessel proximal to injury **OR**
  - Time duration is greater than or equal to 20 minutes
- Critical Management Error
  - Delay going to the OR **OR**
  - Inappropriate use of CT scan or Angiogram
- Non-Critical/Morbidity/Other Management Error
  - Fails to obtain chest x-ray **OR**
  - Fails to prep entire chest **OR**
  - Fails to prep entire arm/hand **OR**
  - Fails to prep the thigh for vein harvest

Brachial Artery

- Critical Technique Error
  - Fails to loop vessel proximal to injury **OR**
  - Time duration is greater than or equal to 20 minutes
- Critical Management Error
  - Delay going to the **OR**
  - Inappropriate use of CT scan or Angiogram
- Non-Critical/Morbidity/Other Management Error
  - Fails to prep entire arm/hand **OR**
  - Fails to prep the thigh for vein harvest

Femoral Artery

- Critical Technique Error
  - Fails to loop vessel (CFA or SFA+PFA) proximal to injury **OR**
  - Time duration is greater than or equal to 20 minutes
- Critical Management Error
  - Delay going to the OR **OR**
  - Inappropriate use of CT scan or Angiogram
- Non-Critical/Morbidity/Other Management Error
  - Fails to prep entire lower extremity
  - Fails to prep the contralateral groin

4:7 *A priori* Sample Size:

The question of whether there was a large enough sample size with 40 ASSET-naïve surgeons enrolled to validate the IPS metric to evaluate performance improvement after ASSET training was addressed *a priori* in sample size calculations. For continuous outcome measures, this 40 surgeon sample size provides 80% and 90% power to detect differences between pre and post training of 0.46 and 0.53 SDs, respectively based on a two-tailed t-test with 5% type I error. For binary outcomes, this sample size will provide 80% and 90% power to detect a 22% and 25% difference in proportions, respectively, between two groups, based on a chi-square test with 5% type I error. Even if a conservative return rate of 90% is achieved, it was estimated that with 36/40 surgeons who were originally enrolled completing pre and post ASSET training evaluations would enable detection of differences of 0.70 SD and 0.82 SD with 80% and 90% power, respectively using a two-tailed t-test with 5% type I error. In the study of before and after ASSET training only one surgeon was lost to follow-up. This occurred early enough in enrolment that another surgeon was substituted and 100% complete data were obtained for 40 surgeon evaluations before and after training.

4.7.1: Statistical Analyses Formulated:

For each of the procedures performed, the scores from two evaluators for each question and assessment were analysed by a linear mixed model, which included time (whether pre and post training) and evaluation (all individual evaluators) as two fixed factors, and all trainees as a random effector. The effect of ASSET training was examined by testing the difference between pre and post training. The variability of evaluators for each assessment was investigated by testing statistical significance of the fixed factor evaluations. All statistical analysis used statistical analysis software SAS version 9.3 with statistical significance at alpha< 0.05. Statistical analysis for surgical performance of Phase 2 residents, evaluated by two real-time evaluators before and after ASSET course training, was compared with a Wilcoxon matched-pairs signed rank test (α=0.05). Paired t-tests were used for continuous measures and chi-square tests or Fisher's exact tests for categorical measures. Pearson's correlation coefficient and Kappa statistic were used for assessing association of Surgeons Self Assessments and both Objective and Subjective IPS evaluations.

4.7.2: Informed Consent and Cadaver Use Approvals:

Informed consent was obtained from surgeon study participants and the process and form (see Appendix V) were approved by the University of Maryland Institutional Review Board (IRB) and the US Army Office of Human Research Protection (OHRP). Cadaver use was approved by the Maryland State Anatomy Board. About 1,800 cadavers a year are donated to the State of Maryland. The State Anatomy Board is located at the University of Maryland, as one of the original participants in the State Anatomy Board, the University of Maryland can purchase cadavers at $450 per cadaver, about half the charges to other Universities. Extensive documentation (about 500 pages describing cadaver procurement, testing, storage, facilities, staffing and safety procedures etc.) was required to obtain the US Army's approval of human tissue use.

4.7.3: Video Cameras and Case-Based Evaluations of Individual Surgeons:

Figure 4.3: *Shows Surgeon Evaluation Process. Using Figure numbers located in bottom left of images (From Figure 1 Top Left Clockwise) shows Mobile Tablet with embedded evaluation metrics and standardized script. Figure 2: Shows Head-Mounted video Camera with Laser pointer worn by surgeon; Figure 3: Slide from Femoral Artery Case-Based Scenario. (Figure 6: Bottom Right) Axillary Artery Exposure. Cadaver head is at 3 o'clock. Figure 5: Script Reader interacting with study Subject. Figure 4: Surgeon focusing laser beam. Slide also shows boom microphone for capturing surgeon "Talk Aloud".*

4.8: Setting for Studies:

The State Anatomy Board Laboratories occupy 1,000 square feet and include 8- 10 cadaver dissection tables in two separate rooms. Each of 6 cadaver dissection tables was instrumented separately (with US Army funding) for the purposes of the study. Included in each individual location instrumentation were a Pan Tilt Zoom (PTZ) overhead camera, an overview camera. A miniature head-mounted camera was worn by each enrolled surgeon participating in the study. A laptop and a 40 inch display screen were available at each cadaver location and these were used to show each surgeon the injuries described in the Case History. X-Rays and other studies linked to the real patient history that the script described were displayed on the 40 inch screen, as the script was read aloud by one of the evaluators.

4.8.1: Enrolled Surgeon Data Collection and Instrumentation:

Surgeons enrolled in the study were sent the Consent Form ahead of their scheduled visit to allow a chance for them to review. On their arrival at the State Anatomy Board the surgeon was introduced to each member of the evaluation team, consisting of two evaluators (one a physician/surgeon [the 'debriefer' at study data collection completion], the other an anatomist [the script reader]), our audio-video technician and myself as the study Principal Investigator. I described the study in detail to each surgeon before enrolment, and answered any questions before the approved consent form was signed and a copy given to the enrolled surgeon. I also acted as an evaluator for over half of the 80 surgeon evaluations required to gather these data.

4.9: Surgeon Case Logs:

A demographics and experience questionnaire (see Appendix VI for details) was completed by all surgeons, requesting information on year of Residency and time since medical school graduation, as well as experience with upper and lower extremity trauma and their confidence level in performing upper and lower extremity surgical procedures. A case log was collected from each surgeon describing exactly which surgical procedures they had participated in as surgeon, or first assistant. Example case logs completed by PGY 2 and PGY 4 surgical residents are shown in Appendix VII These case logs were analysed and experience categorized into low, moderate and high levels of trauma patient management (Table 4.4).

Table 4.4: The Low, Moderate and High Levels of Experience of the Resident Cohort

Resident Participant Surgical Experience with Trauma Patients

Trauma Patients Evaluated	Low	30 to 100
	Moderate	120 to 200
	High	250 to 550
Upper Extremity Vascular Repairs	Low	0 to 1
	Moderate	2
	High	3 to 35
Lower Extremity Vascular Repairs	Low	0 to 1
	Moderate	2 to 5
	High	6 to 35

4.10: Audio-Video Data Collection:

The surgeon had a head-mounted duplex audio-recorder with boom microphone (see Figure 4.3 above and Figure 4.5 below) placed to record all comments in response to questions posed by the script reader. A ceiling-mounted directional microphone above each cadaver table captured comments of the entire group of surgeons and their evaluators. The head-mounted miniature camera also captured audio of the surgeons and the script reader. A belt-clip-placed transmitter sent the audio comments from the boom microphone to an audio mixer. The Head camera images and audio from the head mounted cameras were stored in the device. The Head camera could collect and store about 60-75 minutes of high definition video at 30 frames per second together with audio. It was necessary to change the Head cameras at least once during audio-video data collection. Our audio-video technician was present for all data collection. A digital video recorder (DVR) recorded PTZ and overview camera images and audio from the hard-wired ceiling mounted directional microphones via the digital audio mixer with time code to match the video images. Both the boom microphone and ceiling mounted camera audio channels were available separately. The surgeon wore a protective surgical gown and gloves, face mask and cap as would occur in a real operating room. An example of a gowned surgeon operating during evaluation by a co-located evaluator is shown in Figure 4.5. The surgeon is wearing a head-mounted camera and boom microphone. The Audio video data collection, particularly the relatively inexpensive head-mounted audio video data collecting camera was very useful for seeing exactly what the surgeon was doing, while the PTZ camera system showed close-up images of the anatomic structures and the ceiling mounted microphones captured the audio both of the script reader and the surgeon responses.

Figure 4.5: *Evaluator and Script Reader are collocated with Surgeon. Note surgeon wearing head camera and boom audio microphone.*

The two cadaver dissection rooms gave considerable flexibility in scheduling our study data collection around other multiple on-going cadaver training uses of the State Anatomy Board facility by the US Air Force and the Shock Trauma Center and the University of Maryland Medical School.

4.11: Real-Time Evaluation Data Collection with an Android Mobile Application*:*

A mobile application (App) was developed as a sub-contract by Swinburne University of Technology, Melbourne, Australia. The final text of the script was prepared following the Consensus Conference and expert revisions, and revisions occurring after preliminary testing with 6 ASSET un-trained novice surgeons (as described earlier in this Chapter). The Swinburne programmers built a touch screen system which included a) the entire instructions of how the evaluations would occur. This script was read to the candidate at the start of the evaluation process; b) the case history script and photographs and X rays associated with each procedure to be evaluated (Appendix II); c) scoring of each individual response with a summary score and wireless printer link; d) The app contained an error link that prevented a positive action link with a negative error; e) to ensure all evaluations were completed, the App would not allow the evaluator to progress onto evaluation of a new procedure until all (and there were about 100-140 different features evaluated for each surgical procedure) evaluation entries were complete. The data collection system (using pencil and paper in the initial studies) was robust when programmed onto a mobile Tablet. This was a very useful to ensure complete data collection. The App also summed each procedure evaluation score before progressing to the next procedure and could provide a summary print out at the end of all the evaluations to give to the candidate. During this study, this feature was not used, as it was felt that this provided too much feedback detail, when these same evaluations would be repeated. In the preliminary study for the initial participants the duration of surgery was not limited to 20 minutes. Only after some surgeons took nearly an hour to complete a single procedure was the duration shortened to 20 minutes after which the surgeon was informed the patient had exsanguinated. So the 20 minute time limit was embedded with timer into the Mobile App. If a surgeon failed to pass a double vessel loop around the correct artery within 20 minutes this was considered to be a technical error. Technical errors were scored as negative two points, if the error was recognized and self-corrected it was scored negative 1 point. A software inter-lock between questions with errors and scoring facilitated summation. The trainer for App use is shown in Appendix III.

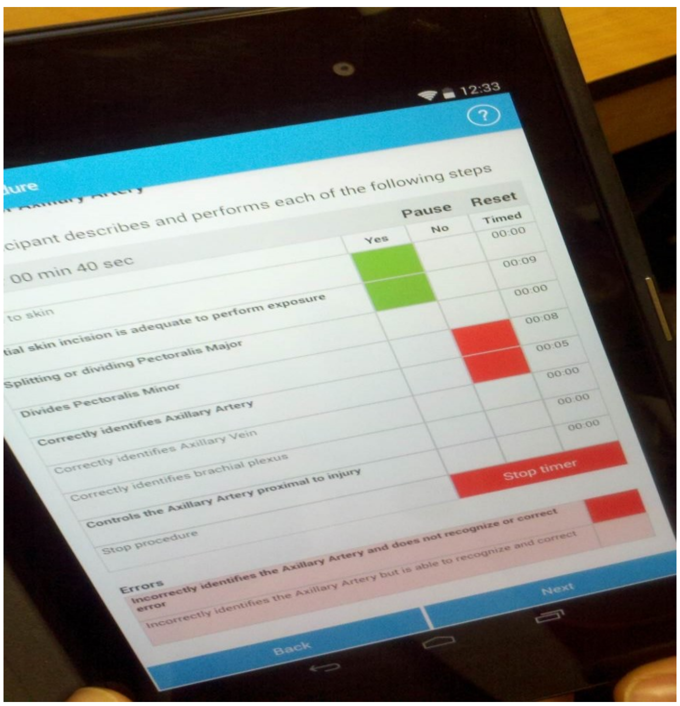


Fig 4.5 A: Tablet Showing RASP App, Script, Case History, and Evaluation metrics

Fig 4.5 B: Detail of Head Cam and Laser direction indicator

The Head Camera was developed during the preliminary testing as a result of a previous study during real trauma patient resuposcitation for which I had team-leader surgeons wear a very early version of a head-camera. The technology is now much more reliable and less expensive (about 100 pounds sterling). The laser direction pointer (about five pounds sterling) enabled us to keep the head camera image focused on the surgeons hands and gave the surgeon an indicator to see where the camera was pointed or to use the beam as a pointer to describe anatomic structures

within the incision. The laser beam in essence acted as a surgeon eye-tracker. As such it was useful to provide situational awareness of where the surgeons gaze was directed, and images of events occurring outside the field of view of the PTZ cameras (e.g. selection of surgical instruments from the instrument tray). The head-camera also allowed visualization of the surgical site when the ceiling-mounted PTZ camera view was obstructed by the surgeon's head.
The preliminary data collection to develop the script and questions and evaluations to inform surgeon performance defined a content along 5 components of Non-Technical (knowledge, management), and Technical skills (procedural steps, surgical technique, anatomy).

4.13: Methodological Issues Considered:

Methodological issues involved in collecting performance data were now considered since the data collection infrastructure was in place to commence the preliminary testing of surgeon performance before and after ASSET course training.

Surgical residents' technical skill is typically evaluated from observations by experienced mentors during training; however this process is time-consuming, labour –intensive and may include evaluator biases. Efforts have been made to standardize surgical trainee evaluations and eliminate bias. I will use the term validity and gather the evidence for validity in the manner as per recommendations published by the Joint Committee on the Standards for Educational and Psychological Testing , the American Educational Research Association, the American Psychological Association, and the National Council on Measurement in Education (2014 Edition). Demonstration of evidence of validity and reliability is a prerequisite for successful scientific measurement of a skill or for evaluation of a performance parameter. Sensitivity or reliability in the metrics (i.e., a Type I error) increases confidence in the validity of the findings. Better validated tools capture underlying skill/performance more accurately, thus minimizing error and bias in data collection. Previously used terms face, construct, and concurrent and predictive validity (72, 133, 156) are not used as these terms have gone out of favour, being replaced with convergent evidence of validity from multiple sources.

4.14: Reliability/Precision:

Reliability/precision is used to refer to the consistency of scores across replications of a testing procedure. A reliability coefficient is a correlation between scores on two equivalent forms of the test. As an example in the Thesis I will describe testing surgeons before ASSET training and then repeating the testing within two weeks of training and comparing an Individual Procedure Score to subjective Global Ratings. The reliability and precision will be assessed by use of multidimensional and systematic observations, and measures including audio-video recording over time during performance of three combat-casualty relevant representative vascular exposure ASSET procedures before and after training. I used this approach as a basis to validate aspects of the ASSET training course.

4.14.2: Validity:

A major challenge to the validity of these data collected on skills of surgeons-in-training is that they will not be collected in the real operational environment. The surgical operating theatre is a unique domain including a team of other professionals such as more senior surgeons, anaesthesiologists, nurses, and technicians, all of whom can profoundly influence surgeon performance. Team members are one more defence against surgeon error. Team factors are an important part of events in the real operating theatre including in studies of surgeon performance, the potential for coercion of either the surgeon or the patient to participate. Assessing skills of surgeons outside this arena is fraught with fidelity and other realism issues.

4.14.3: Fidelity of Cadaver:

Another challenge to the validity of this study is that surgery was performed on cadavers. There was no bleeding, no tissue injury to distort anatomy and none of the movements or physiology (such as breathing) or psychology of operating on a living person. The fidelity of cadaver tissue is different than living tissue and this can distort a surgeon’s dexterity, instrument handling and perception of anatomy. Chief among these limitations to tissue and physiology of the cadaver, especially when vascular surgery is the surgical task under study, are the cool temperature of tissues and the lack of vascular pulsation. Many surgeons in the study remarked on the lack of pulses, when searching for one of the three arteries they were asked to expose.

4.14.4: Assessment Tools:

The assessments tools should be psychometrically robust to capture technical skills, (104, 157). Recent systematic reviews detail the need for psychometric robustness of technical (140) assessment measures. Moreover, training evaluators in tool use, as was done for the evaluators used in the Thesis, should be considered a prerequisite for performance research. Training evaluators is part of establishing validity of the assessment and quality control; it ensures assessments are truly comparable within and between studies. "As Hull has stated "our understanding of the interactions between (158) the specific skills and technical performance increases, tailor-made training packages aiming at specific skills for specific grades of surgical expertise can be developed, implemented and evaluated"(140).

4.15: Solo Performance versus Team Performance:

In defence of examining solo surgeon performance versus surgeons operating as members of a surgical team that would include anaesthesiologists, nurses and technicians: it was not my intent to study operating theatre teamwork, as teamwork and non-technical skills in the operating theatre has been extensively studied already (40, 41, 43, 112). It was a purposeful intent of this Thesis to study solo performance of a surgeon operating not as a member of a team, but independent of any support or advice from others. In some field and military situations this may be exactly the circumstances in which a surgeon is asked to perform, when they may never have had to operate solo before. In addition this is the ultimate test of Miller's "does", in which the surgeon alone shows the evaluators that they <u>can</u> do the exposure and control the correct vasculature (10). The results for these surgeons-in-training were quite surprising because of having no senior surgeon input, more critical errors occurred than one might have expected (see Chapter 8).

Another reality limitation of the study was that as a result of operating solo, the surgeons had to locate and select surgical instruments from a limited supply of instruments, although the evaluators did offer to hold retractors or find additional instruments, the evaluators did not suggest which instruments were appropriate and many surgeons struggled because they did not use the available instruments e.g. self- retractors. The surgeons were not stressed, as they may be in the real operating theatre, although they knew from the case-based scenario that the "patient" was bleeding from a major vessel and they were told they would have 20 minutes to gain exposure and vascular control by passage of a double vessel loop around the requested blood vessel. The surgeons received a countdown to 20 minutes at 15 and 19 minutes after skin incision, at 20 minutes they were told the patient had exsanguinated, and the next case scenario was begun. Intentionally applying stressors to surgeons while operating is unacceptable during real surgical procedures. Applying such pressures and allowing surgeons to make mistakes and errors of judgment is however acceptable in non-clinical simulated situations and is a recognized advantage for training in the cadaveric laboratory.

4.16: Study Biases:

Several types of biases were inherent in the evaluations conducted for the Thesis studies. Study biases were considered under three domains (2, 159) of participant selection, index test and reference test. The revised Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) is a seven question tool to assess the quality of reviews of diagnostic studies. I used this framework to show that data collection minimized bias by avoiding elective inclusion of specific groups of surgeons. Other sources of bias include incomplete descriptions of study populations and lack of rater-blinding. As will be seen below although the co-located evaluators were not blinded, use of randomly ordered video recordings enabled blinding and remote independent evaluator review to make unbiased review for surgeon performance assessment. Three biases will be considered, learning bias, training bias and evaluator bias.

4.16.1: Learning Bias:

Learning bias occurred because the surgeons were assessed with exactly the same script before and after ASSET training. This had two effects, firstly the surgeons only realized how much they did not know about some of the procedures they were asked to perform after they performed them for the first time. This was documented in some of the surgeons by a reduction in self-reported confidence in comparison to their own self-reported confidence immediately before the procedure (see Chapter 7). As a result of this realization that they knew less about these procedures than they had thought they did, it is probable that these surgeons paid special attention to these procedures during training. All surgeons were scheduled within 2- 4 weeks to take the ASSET Course, and were given the ASSET course handbook <u>after</u> the Pre-ASSET training evaluations. The potential for learning bias was accentuated by the debrief each surgeon received after completion of all the cadaver procedures. As part of the larger US Army funded study, these same surgeons were re-evaluated 6 months to 18 months later, again using the same script with requests to perform the same procedures. In order to determine if there was learning bias we introduced a 'surprise' additional vascular surgical procedure, carotid artery exposure and control. This procedure had been included among those taught in the ASSET Course but had not been used in the repeated testing. These data are not reported in the Thesis, however, the results did not support evidence of learning bias.

4.16.2: Training Bias:

The ASSET Course instruction took place independently of the Thesis study. Because of this independence of the ASSET course, training bias in which the study surgeons would be "trained for the test" seem unlikely.

4.16.3: Evaluator Bias:

Surgeons were enrolled into the study, received training by attendance at the ASSET Course and were re-evaluated within, at most, 6 weeks. Some evaluators knew they had evaluated the same surgeons recently and these evaluators know that the second evaluation was scheduled after training. Although 15 evaluators were trained, each surgeon was evaluated by two co-located evaluators, so at least one usually knew the surgeons status of training. To address this bias video recording were reviewed of surgeon technical skills (from a head-camera worn by each surgeon, so only the hands and surgical site were visible). The video recordings were randomly arranged so that reviewers were unaware of the status of surgeon training or the surgeons identities in recordings made for each surgical procedure, before and after training. Because 40 surgeons were evaluated before and after training, and each surgeon performed all 3 vascular control procedures there was a need to minimize the workload of video review. In addition, because some enrolled surgeons performed better than others, there was a spectrum of pre ASSET training performance. The lower performing surgeons before taking the ASSET course had greater opportunity to improve performance with training than did already high performing surgeons. The methods and results are discussed more fully in Chapter 8.

4.17: Variability of Experience:

All the surgeons in the cohort were still in training. However, among the surgeons enrolled in the study there was a variability in experience (surgeons were 2-6 years in-training) and many had experienced more trauma and vascular surgery than others. Surgeon case-logs (such logs are a requirement of the American College of Surgeons for entry into their Board Examination) data were collected (as described previously, experience levels were divided into 3 levels of high, medium, and low based on the cohort tertile) and accounted for in the models of performance, as was cadaver body habitus (obese, normal, or thin) and unique cadaveric anatomic anomalies.

4.18: Chapter 4 Summary

The Methods included development of a standardized script with embedded Technical and Non-technical skills checklist and 5 Global Rating Scales. Three categories of errors were developed by consensus. Considerations in the design, analysis, sample size and validity testing were made before Preliminary testing with the finalized script, was begun. The Aims of Chapter 4 were explained including Thesis Design, Methods, Preliminary Analyses and Potential Biases. Chapter 5 reports preliminary data that address the comparison between surgeons' self-evaluations with expert derived Global Rating Scales of performance.

Chapter 5: Comparison of Surgeon Self-Evaluated Performance with Global Ratings of Performance.

5.0: Overview of Chapter 5:

Chapter 5 reports a study testing the surgeon's belief that they can accurately judge their own performance and are able to self-detect their own deficiencies and errors. Current training is most commonly assessed by knowledge-based written tests and peer review. Written tests cannot evaluated technical skills and peer review can be biased. The aim of this chapter is to compare surgeon self-evaluation of confidence questionnaires completed by surgeons enrolled in this Thesis effort to those of the global performance metric which were developed in addition to the individual procedure score were described in Chapter 4.

5.1: Introduction:

Early in Chapter 1, the lack of open surgical procedures for trauma was identified as a capability gap in training of US surgeons. Because the impact of the reduction in exposure to open surgery might not be apparent to the generation of surgeons in training 10 years later, a survey of self-perception of skill was undertaken. Self-perception was compared to evaluation using Global Rating Scales (GRS) to see whether surgeons identified their dimished exposure to open surgey as causing reduced skill. Several other investigators have identified the limitations of self-identification of skills performance (160-162), while other studies have shown correlation with independent evaluator scores.

The Aim of Chapter 5 was to compare surgeon self–evaluations before training with GRS evaluations made by trained evaluators while they performed axillary (AA), brachial (BA), and femoral artery (FA) exposure and vascular control procedures. The hypothesis tested was that the resident participants self-reported perception of skills and knowledge does not equal reality of operative performance during AA, BA and FA procedures judged by trained evaluators.

5.2: Methods:

Surgical residents, who had not taken the ASSET course or received the course materials were asked to perform three of the skills taught in courses held between August 2013 and July 2014. Forty-two surgical residents from 11 different residency programs in the greater Baltimore area and adjacent states were recruited to participate. Data from ten of these residents were used to establish a baseline performance on three skills taught in the ASSET course; exposure and control of the axillary artery, brachial artery, femoral artery (common, superficial femoral (SFA), and profunda) at the groin, before participation in the course. The other 32 residents were among 40 surgeons enrolled in the longitudinal study to validate training benefits of the course.

Global ratings (using a 5-point Likert scale) for each procedure rated the overall understanding of the surgical anatomy and included an assessment by the evaluator whether the participant was currently ready to perform the procedure in question (Table 5.1).

Table 5.1: Shows representative Global Rating Scales for Axillary Artery Procedure including Evaluation and Treatment (G1); Surgical Anatomy (G2); Technical Skills (G3); Readiness to Perform (G4), and an Overall Evaluator Rating (%).

AXILLARY ARTERY EXPOSURE GLOBAL RATING (circle one)**:**

G1: Overall Understanding of the Evaluation and Treatment of a Patient with a Suspected Axillary Artery Injury:

Score: 1	**2**	**3**	**4**	**5**
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.

G2: Overall Understanding of the Surgical Anatomy of the Axillary Region:

Score: 1	**2**	**3**	**4**	**5**
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.

G3: Technical Skills for Exposing the Axillary Artery:

Score: 1	**2**	**3**	**4**	**5**
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.

G4: This participant is ready to perform exposure and control the Axillary Artery:				
Score: 1	**2**	**3**	**4**	**5**
The patient has exsanguinated. Participant is not ready to perform the exposure.	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.

ER: Evaluator's overall rating (1-100)

≥ 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 The patient has exsanguinated. Participant is not ready to perform the exposure.

The overall score should be the instructor's subjective rating of how well the surgeon performed. This will be compared to the objective score for the purpose of validating the scoring method**.**

BH: Body Habitus of cadaver (Circle):

Obese	Average	Thin

CA: Cadaver Anatomy (Circle):

Normal	Variant

5.3: Evaluator Ratings and Cadaver Notations:

In the overall evaluator rating of 1–100, 100 was the idealized "expert" surgeon performance, whereas <60 was associated with the description "The patient has exsanguinated- The participant is not ready to perform the procedure. Take me to another hospital please!" The cadaver body habitus was noted for each procedure (habitus could vary by procedure due to differences in body fat distribution e.g. brachial artery could be surrounded by fat in an otherwise thin cadaver). There was also notation made of any anatomic anomalies in vascular exposure (e.g. the profunda femoral artery has superior or inferior take off points from the common femoral artery in relation to the inguinal ligament). These body habitus and anatomic variants were accounted for in the linear mixed models used to compare performance before and after training.

5.4: Study Procedure:

Resident surgeons were asked to complete a demographic questionnaire that detailed their level of training and their self-reported experience with the management of trauma cases. They were asked to state the number of vascular procedures performed for the upper and lower extremity. Additionally, the subjects were asked to rate (on a 5-point Likert scale) their current confidence in their understanding of the anatomy required to perform as well as their current confidence in their ability to perform vascular exposure and control of the axillary artery; the brachial artery; the femoral artery (common, SFA, and profunda) at the groin (Demographics questionnaire is in Appendix III). The surgeons then each performed all three procedures as directed by the case-based standardized script without any coaching or correction of errors. They were allowed no more than 20 minutes to complete each of the procedures. The performance assessment tools were used by two real-time evaluators to include the script reader and a silent second expert evaluator. All data points for the individual procedure score (IPS) performance assessment tool were collected, but for the purpose of this study, specifically global ratings were extracted for understanding of anatomy and the evaluator's assessment of whether the resident was currently able to perform the procedure for the three procedures in question. Additionally, the overall global (1–100) rating by the evaluators for each of the three procedures was collected. The residents' level of training, self-reported trauma experience and case numbers, self-assessed knowledge of anatomy, and confidence in their ability were compared to the global ratings provided by the evaluators for each of the procedures. Statistical analysis was accomplished using the t-test (modified for unequal variance) and the Pearson product-moment correlation coefficient with α set at $p < 0.05$.

5.5: Results of Self-Assessments and Procedure Performance:

The 42 surgical resident subjects in this study included 19 PGY 3 (45%), 15 PGY 4 (36%), and 8 PGY 5 (19%). The average age was 31.8 ± 3.1 with a range of 27–41, and 24 (57%) were male. Self-reported months on the trauma service, number of trauma patients treated, percentage of penetrating trauma, and numbers for specific cases are detailed in Table 5.2. The median time spent on the trauma service was 4.5 months with 100 trauma patients evaluated/treated of which 10% had penetrating trauma.

Table 5.2: **Self-reported trauma patient evaluation and relevant operative experience of 42 surgical residents (includes average plus or minus standard deviation, the range, and median) Demographic Information is described in Appendix VI: Surgeon Demographics and Experience Survey completed by all participants.**

Self-reported trauma patient evaluation and relevant operative experience of 42 surgical residents(includes average plus or minus standard deviation, the range, and median)

Self-reported experience	Average	Range	Median
Months on trauma service as resident	5.66 ± 3.7	1–16	4.5
Number of trauma Patients treated	158 ± 129	10–650	100
Percent with penetrating trauma	19.8 ± 18.7%	0–80	10%
Number of upper extremity open trauma vascular cases	1.37 ± 1.6	0–5	1.0
Number of lower extremity open trauma vascular cases	2.7 ± 3.7	0–20	2.0
Number of lower extremity open non-trauma vascular cases	21.4 ± 19.7	0–100	15
Number of lower extremity trauma fasciotomies	3.05 ± 3.7	0–16	2.0
Number of lower extremity non-trauma fasciotomies	3.19 ± 3.0	0–10	2.0

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The median self-reported operative caseload for vascular trauma were low as expected, ranging from 1–2 cases, with non-traumatic exposure of the femoral artery with a reported median of 15 cases (Table 5.2). When compared to the ACGME National data set for graduating chief residents, it is important to note that the averages self-reported by the residents in this study are well above the national averages and would place them in most instances above the 70th percentile, even though the majority (81%) are still PGY 3 and 4 (163). However, it is also important to note that these numbers are self-reported and were not verified by actual case log entries.

The residents' self-assessed comfort with their understanding of anatomy and their self-assessed confidence in their ability to perform each exposure or procedure (rated on a 5-point Likert scale) were compared with the evaluators scoring of each individual (5-point Likert scale) on their global understanding of the anatomy for each procedure and their current ability to perform each procedure independently.

As seen in Table 5.3, residents rated themselves significantly higher when compared with expert evaluators in their understanding of the anatomy required to perform all three tasks. Additionally, residents rated their current abilities to perform the majority of tasks (brachial artery and femoral artery exposures) significantly higher than did the expert evaluators with a trend toward the same for the axillary artery exposure.

Table 5.3: The self-assessed confidence levels (5-point Likert scale) of 42 surgical residents for their understanding of the anatomy required, and their confidence in their ability to perform each of the three listed procedures compared with the global scores of evaluators on the same items. Values are reported as the mean ± the standard deviation.
Statistical analysis was accomplished using the modified t-test for unequal variance with α set at P < 0.05.The values in bold represent statistical significance.

Procedure	Understanding of anatomy			Confidence of performance		
	Resident	Evaluator	P value	Resident	Evaluator	P value
Expose axillary artery	2.50 ± 0.83	1.99 ± 0.95	<0.005	2.14 ± 0.74	1.90 ± 0.74	<0.09
Expose brachial artery	2.60 ± 0.85	2.14 ± 0.73	<0.005	2.40 ± 0.76	2.07 ± 0.74	<0.03
Expose femoral artery	3.58 ± 0.70	2.78 ± 0.90	<0.0001	3.21 ± 0.77	1.96 ± 0.54	<0.00001

The average global score for axillary artery exposure and control was 61.8 ± 12.9; for brachial artery exposure and control 64.0 ± 10.8; and for femoral artery (common, SFA, and profunda) exposure and control 66.8 ± 9.72.

The evaluators' confidence of each resident to perform the three procedures was compared with each resident's self-assessed confidence in their ability to perform these procedures as listed in Table 5.3: To further examine these differences and the current state of resident preparedness to do these procedures, frequency histograms were constructed for the responses from both the residents and the evaluators

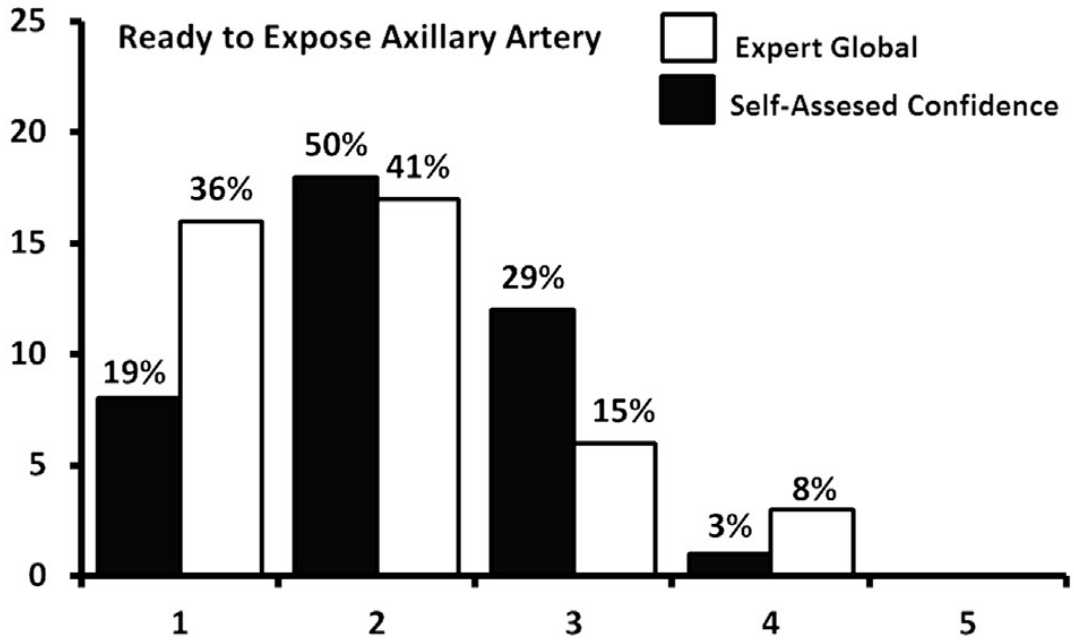


Fig. 5.1. *Histogram of the frequency (y-axis) of each numbered Likert scale response (x-axis) provided by the self-assessment of the 42 residents compared with the expert evaluators global assessment for exposure and control of the axillary artery. The relative percentages of each of the frequencies are listed above each Likert scale response. Seventy-seven percent of residents received a score of 2 or less by evaluators, and residents tended to rate themselves higher.*

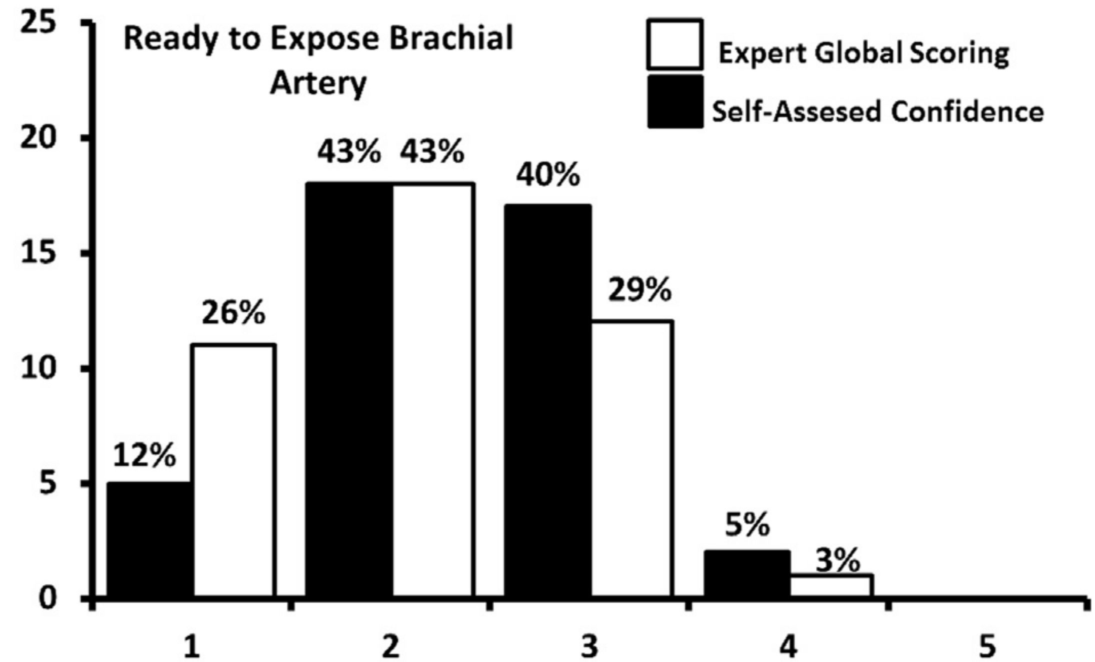


Fig 5.2. *Histogram of the frequency (y-axis) of each numbered Likert scale response (x-axis) provided by the self-assessment of the 42 residents compared with the expert evaluators global assessment for exposure and control of the brachial artery. The percentages of each of the frequencies are listed above each Likert scale response. Sixty-nine percent of residents received a score of 2 or less by evaluators, and residents tended to rate themselves higher.*

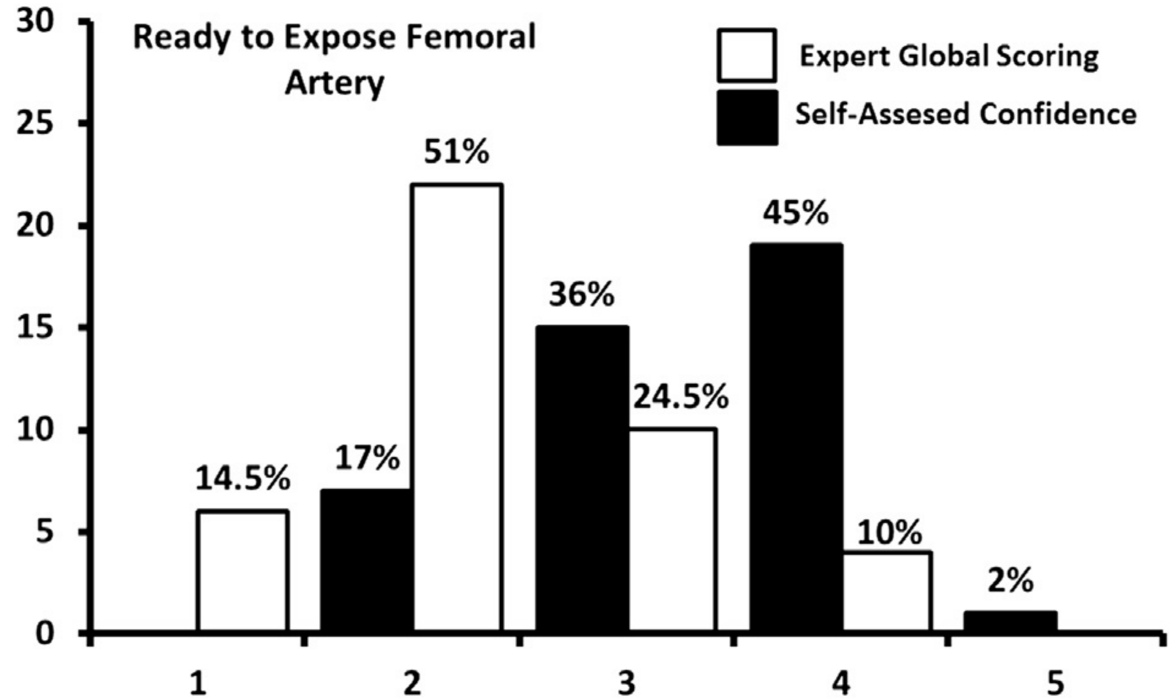


Fig. 5.3. *Histogram of the frequency (y-axis) of each numbered Likert scale response (x-axis) provided by the self-assessment of the 42 residents compared with the expert evaluators global assessment for exposure and control of the femoral artery. The relative percentages of each of the frequencies are listed above each Likert scale response. Sixty-five percent of residents received a score of 2 or less by evaluators, and residents rated themselves significantly higher.*

5.6: What Do These Results Mean?

As seen in Figure 5.1 for exposure and control of the axillary artery, 36% of residents were scored by evaluators as a 1 on the Likert scale defined as: “The patient has exsanguinated—This participant is not ready to perform the exposure.” Another 41% were scored as a 2 on the Likert scale defined as: “This participant could do the exposure only with experienced help, but will struggle if left alone.” Evaluators scored 15% of the residents as a 3 on the Likert Scale defined as: “The participant might need to look at a text to refresh their memory but will be able to perform the exposure.” The final 3% were scored as a 4 on the Likert scale defined as: “This individual will be able to perform the exposure with minimal difficulty in an expeditious fashion." None of the residents were scored at the highest level (164) defined as: "Absolutely prepared, I hope that this individual is on call if I am injured." As scored by the expert evaluators, 77% (Likert scores of 1 and 2) of the residents would not be able to do this procedure independently and another 15% (Likert score 3) would be able to perform it only after looking at a book, limiting their effectiveness in a true emergency. In the opinion of the evaluators, only 8% of the residents would be able to immediately perform an adequate exposure and control of the axillary artery in a bleeding trauma patient.

Figure 5.2 shows similar results with 69% of residents receiving a score of 2 or less and 97% receiving a score of three or less and only the remaining 3% receiving a score of 4 by evaluators when asked to rate the residents ability to perform exposure and control of the brachial artery. As seen in Figure 5.3, there was a very pronounced difference between the residents' self-assessed ability to perform exposure and control of the femoral artery and its branches compared with that of the evaluators. The evaluators assigned a score of 2 or less to 65.5% of the residents with 14.5% receiving a score of 1, compared with the residents who rated themselves a 2 only, 17% of the time, with no resident rating themselves as a 1 for exposure and control of the femoral artery. Residents rated themselves a 3–5, 83% of the time compared with 34.5% for the expert evaluators with no scores of 5 given.

Further analysis of the data was accomplished using the Pearson product-moment correlation coefficient to look for potential correlation between the collected variables. Specifically, there were no significant correlations between PGY level and self-assessed understanding of anatomy of the axillary, femoral, or lower leg (range $r = 0.02–0.24$), although there was a modest positive correlation between PGY level and self-assessed understanding of anatomy of the brachial artery ($r = 0.34$, $P < 0.03$). There was no correlation between PGY level or number of months spent on the trauma service and self-assessed confidence to perform the procedures (range $r = 0.01–0.26$). There was a positive correlation between PGY level and the evaluator global rating for knowledge of anatomy of both the femoral artery ($r = 0.43$, $P < 0.005$) and the lower leg ($r = 0.32$; $P < 0.04$). A positive correlation did exist between a self-assessed understanding of anatomy and self-assessed confidence in the ability to perform the procedures with $r = 0.62$

($P < 0.001$) for axillary, $r = 0.64$ ($P < 0.001$) for brachial, $r = 0.71$ ($P < 0.00001$) for femoral arteries. There was also a significant positive correlation between how the evaluators rated the participants understanding of anatomy and their ability to perform the procedure with $r = 0.68$ ($P < 0.0001$) for brachial, $r = 0.78$ for femoral, and $r = 0.85$ for axillary with $P < 0.00001$ for the latter three. Finally, there was no correlation between self-assessed knowledge and confidence to any of the global scores (range $r = -0.03$ to 0.16).

5.7: Discussion of Surgeon Confidence and Implications for Solo Practice:

The baseline knowledge of the anatomy required to perform the studied procedures and the global confidence of the expert evaluators that the individual residents could independently perform these procedures were low. The residents consistently rated their knowledge and abilities higher than the expert evaluators ultimately scored them. A number of other studies have looked at the comparison of self and external assessment for cognitive and technical tasks in surgery (160, 165-168). In a comprehensive review of the literature, Zevin (160) found mixed results regarding an agreement between self and external assessment scores for technical tasks in surgery with 53% showing agreement, 24% reporting higher self, versus external scoring, and 18% reporting a lower self, versus external assessment scores. The present study found that the self-assessment by the surgical residents was significantly higher than the external expert assessment scoring. Human factors have been implicated in this phenomenon of higher self, versus external assessment scores (160, 165-166, 169). Evans et al. (167) have described and examined factors to include self-deception defined as the lack of insight into one's incompetence. Dunning and Kruger (167) proposed that, for a given skill, incompetent people will: fail to recognize their own lack of skill, fail to recognize the extent of their inadequacy, fail to accurately gauge skill in others, recognize and acknowledge their own lack of skill only *after* they are exposed to training for that skill. Evans, Dunning and Kruger's findings could provide explanations for the mixed results seen in prior performance self-assessment studies. This study was not designed to tease out these potential factors, but it appeared that self-deception was a predominate factor in most participants.

Many of the residents appeared to be surprised and embarrassed by their poor performance, and there was an interesting effect on their apparent level of subsequent preparation for the actual ASSET course compared with that of contemporaries not involved in the study. The differences between self and expert assessment of scores were most pronounced for exposure and control of the femoral artery. This finding is likely due to the increased self-reported exposure by resident to femoral artery exposures for both trauma and non-trauma (average of 24 and median of 17 cases), prompting an unwarranted confidence in both their understanding of the anatomy and the ability to independently perform these procedures. This finding underscores the fact that competence is not merely a function of numbers or exposure to procedures, but deliberate practice of and reflection on proper performance of the procedures, guided by a relevant understanding of the underlying anatomy.

5.8: Conclusions of Resident Self –Evaluation of Performance:

Senior surgical residents were found to be inadequately prepared to perform vascular exposure and control of the axillary, brachial and femoral arteries. These findings, coupled with the residents unwarranted (as judged by expert evaluators) levels of self confidence in their abilities identifies a serious problem for surgical educators. The residents' perception of their ability to perform each of the procedures clearly did not meet the reality of the evaluations. Program directors responsible for the surgical education of these residents would probably be surprised by the results.

This study shows that surgical trainees are not being adequately prepared to perform and training for vital but infrequently performed procedures needs a significant review and change to more effective and validated curricula. The lack of anatomic knowledge demonstrated by residents in this study is also serious. An emphasis on sound relevant surgical anatomy, coupled with exposure to correct performance and deliberate practice of specific procedures, may well be the foundation for sound curricular change. Courses like ASSET and increased use of simulation-based training may help to influence future curricular changes. The self vs expert evaluation of residents' ability provides a clear finding that resident trainees are unaware of their lack of competence in technical and non-technical skills for emergency vascular exposure and control. This provides a rationale for rigorous examination of individual surgeon performance with validated metrics, before and after training. In Chapter 6, I report pilot data and an interim analysis that address this need using the Individual Procedure Score metric.

Chapter 6: Pilot Validation of Individual Procedure Score Metric and Standardized Script; Preliminary Inter-Rater Reliability; Initial Findings of Expert versus Un-trained Surgeons.

6.0: Overview of Chapter 6:

The Aim of Chapter 6 is to report the interim analyses carried out using the tools developed as a result of the efforts described in Chapter 4. Before enrolling a large number of surgical residents. I thought it prudent to do an interim analysis on the first cohort of surgeons tested before and after ASSET training. Testing in the first 12 enrolled surgeons would show whether IPS and GRS metrics showed change with ASSET training and would assess the reliability of evaluations and their validity to inform any needed changes to data collection tools or analyses before more surgeons were enrolled.

6.1: Interim Analyses of Surgeon Performance Before and After ASSET Training:

Before launching into enrollment of large numbers of surgeons into the study whose design was described in Chapter 4, a preliminary validation was undertaken. The Aim was to test the study concepts, methods and planned analyses and assess validity of the proposed methods and metrics. As preliminary proof-of-concept, we tested surgical performance metrics with single ICC > 0.70 in 12 surgical trainees (residents in clinical year of training 3-7, none of whom participated as novice surgeons in the formative evaluation development described in Chapter 4). These twelve surgeons were assessed before and within 2 weeks after vascular exposure surgical skills training carried out by instructors for the Advanced Surgical Skills for Exposure in Trauma (ASSET) course. ASSET course content includes the 3 procedures (AA, BA, FA) evaluated in this thesis from among a total of 59 procedures taught during the course.

6.2: Pilot "Proof of Concept" Testing among Resident Surgeons: Inter-Rater Agreement, ICC Analysis Technical skills and Correlation Pre- Post Training Questions and TRI:

Video of expert and novice surgeon hands performing AA, BA, FA procedures were randomly arranged. Intra-class correlation coefficients (170) (ICC) were used to compare inter-rater reliability of 5 trained evaluators viewing the randomly arranged video with no indication of whether these were experts or novice surgeons. The Head-camera video only showed the surgeons hands with no audio (to prevent voice recognition or surgeon identification). Technical skill metrics with single ICC > 0.70 were included in this before and after ASSET training evaluation. Among 10 technical skills analysed using the blinded video as the source material, 4 skills metrics had single ICC > 0.70 sufficient to be included in the summed evaluations for the 3 procedures (Trauma Readiness Index = TRI). The single ICC and the average ICC for consistency for the rating of the 10 novice surgeons are shown in Table 6.1. Due to limitations with video review, technique points 1 and 2 could not be evaluated by all reviewers. Only technical skills 5, 7, 8 and 9 were selected by video review for inclusion in the TRI.

Table 6.1: Surgeon Technical Skills with Intra-Class Correlation Coefficients (ICC).

		Intra-Class Correlation	
1	**Exposes arteries by dissecting directly on anterior surface**	Single	0.5
		Average	0.84
2	**Manipulates artery by grasping adventitia**	Single	0.2
		Average	0.55
3	**Uses instruments properly**	Single	0.3
		Average	0.68
4	**Positions body to use instruments to best advantage**	Single	0.41
		Average	0.78
5	**Proceeds at an appropriate pace with economy of movement***	Single	0.8
		Average	0.95
6	**Handles tissue well with minimal damage**	Single	0.36
		Average	0.74
7	**Creates an adequate visual field using retractors for procedure***	Single	0.78
		Average	0.95

8	**Communicates clearly and consistently***	Single	0.77
		Average	0.94
9	**Performs procedure without unnecessary dissection***	Single	0.72
		Average	0.93
10	**Continually progresses toward the end goal**	Single	0.69
		Average	0.92
*single intra class correlations > 0.70 metrics included in Trauma Readiness Index			

6.3: Surgical Performance in Un-Trained Resident Surgeons Relative to Idealized Performance (100 percent correct):

The evaluation scores of the untrained resident surgeons were calculated for the axillary artery, brachial artery, and femoral artery exposures procedures. The mean Trauma Readiness Index score for all procedures was 50 percent. Scores for each procedure are detailed in Table 6.2 below. In a single sample t-test, all of these scores differentiate significantly from idealized performance (100 percent, $p<0.001$). Procedure evaluations were conducted prior to the institution of the 20 minute surgical procedure allowance. Without a sense of urgency, all procedures were performed within an average of 16.8 minutes with a range of 5 to 58 minutes.

Table 6.2: Detailed Results of Untrained Surgeon Scores, n=10 (all are significantly different from idealized performance, 100%, *p*<0.001 in a single sample t-test). TRI, Trauma Readiness Index; St Dev, Standard Deviation.

	All Four Procedures		Axillary		Brachial		Femoral	
	Mean	St Dev	Mean	St Dev	Mean	St Dev	Mean	St Dev
Time	16.8	9.4	14.4	14.4	6	20.5	5.3	16.2
Knowledge								
• Overall	58	11	50	9	68	11	57	7
• Anatomic	54	19	58	15	42	20	58	12
• Management	46	16	37	15	64	12	42	9
Procedure steps	43	28	48	29	24	28	51	21
Technical Skills	48	10	56	42	53	39	38	39
TRI/Procedure score	50	14	49	12	47	18	54	9

6.2: Methods for Interim Validation of Surgeon Evaluations Before and After ASSET Training:

Surgical performance of the 12 surgeons was assessed by pairs of trained evaluators, with one trauma-physician and one non-surgeon-anatomist investigator assessing each surgeon's performance. Data on surgeon responses to knowledge questions and technical performance were captured during the procedures by completion of the responses and scores integrated into the script. A maximum of twenty minutes was allowed for the completion of each of the three procedures. For each surgeon, scores were calculated in each area of assessment (overall knowledge, anatomic knowledge, patient management knowledge, procedure steps, and technique points) as a percentage of total available points. To provide a discrete metric to identify "readiness" to perform these procedures, the Trauma Readiness Index (TRI) was then calculated as the sum of points awarded for all three procedures and remaining time allowed divided by the sum of possible points and time allowed. Two definitions of TRI were used.

Table 6.3: Definition Trauma Readiness Index (TRI) and Individual Procedure Score (IPS) and Adjusted TRI and IPS.

Trauma Readiness Index (TRI) is the mean of all IPS scores calculated using the 'Mean' of two evaluator ratings. Two values for TRI and IPS are used depending on whether the analysis is detecting Errors (Error analyses include timing and critical technical management and morbidity errors). The adjusted TRI and IPS are used for detecting errors.

- TRI for vascular procedures with errors and time included
- Adjusted TRI (TRI without time or errors included)

6.5: Results of Preliminary Surgeon Performance Analysis:

6.5.1: Preliminary Comparison of Surgical Skills Before and After ASSET Training

Twelve surgeons were evaluated using the knowledge questions, procedure-based checklists, and ~~3~~ validated technical skills before and after ASSET training. The difference in pre- and post-training scores is illustrated in Figure 6.1.

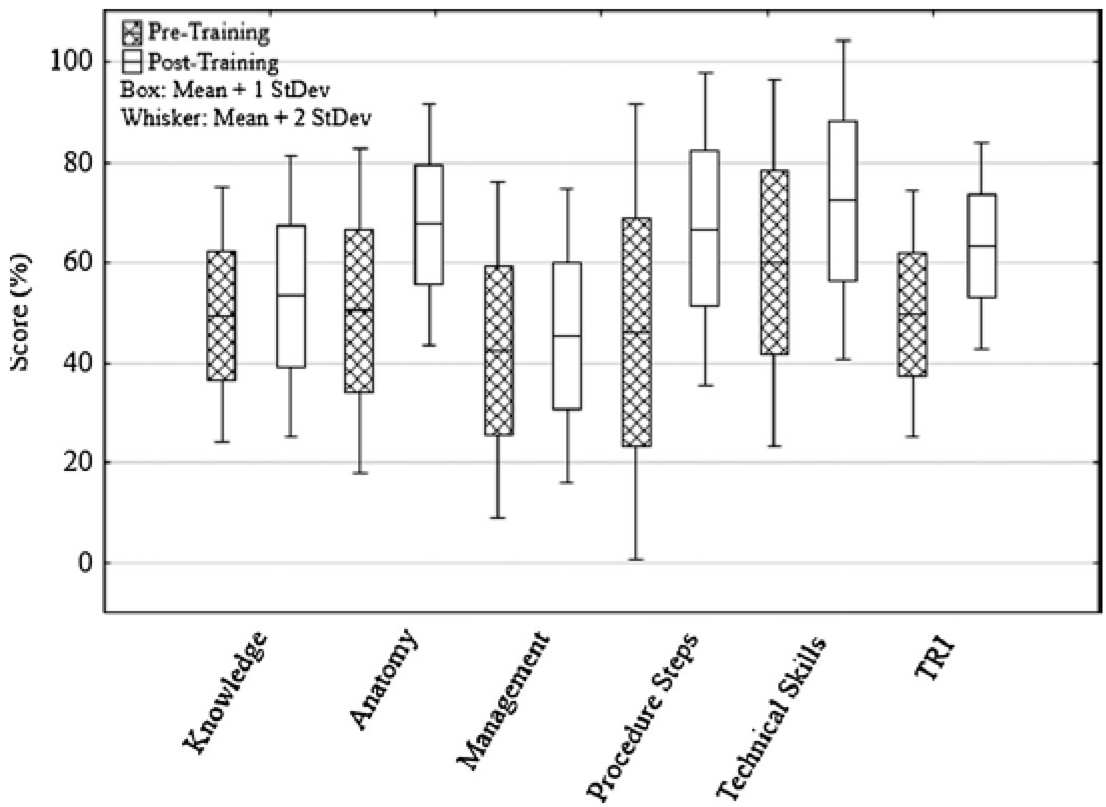


Figure 6.1: Individual Procedure Score (IPS %) on Y Axis is plotted against components of IPS on X axis. Hatched = Pre- ASSET Training, Open = Post-Asset Training in 12 surgeons.

The mean time for completion of each of the three specific procedures decreased significantly from 13.4 minutes before training to 9.1 minutes after training ($p<0.001$).

Surgical trainees assessed at baseline before ASSET training achieved an average of 50 percent of the idealized expert surgeon performance score for overall knowledge, 46 percent for procedure steps, and 60 percent for technical skills.

After completing the ASSET course, the specific skill most improved by the 1-day skills course was procedure steps, which improved proportionally by 21 percent after training. Anatomic knowledge was also strongly impacted by training, with 18 percent increase in mean scores for this metric. A 12 percent improvement in technical skill scores occurred after training, although technical skills were not specifically emphasized during the training. No improvement in patient management knowledge was detected, a field not addressed by the training. The Trauma Readiness Index was 50 percent of the expert surgeon performance before training and was improved by 14 percent after training. Pre and post-training scores are displayed in Table 6.4. The cost involved in the assessments was modest (about $ 2,500 per enrolled surgeon, including cadavers, laboratory and evaluator fees, and travel costs).

Table 6.4: Surgical Performance Assessment Scores Pre- and Post- Training showing significant improvements in Procedural Steps, Technical Skills, and Trauma Readiness Index as a % of idealized expert surgeon performance.

	Pre-training		**Post-training**			
	Mean	Std Dev	Mean	Std Dev	Improvement %	*p*-value
Time (minutes)	13.4	5.9	9.1	4.5	-4.3	<0.001
Knowledge score						
• Overall	50	13	53	14	3	0.013
• Anatomic	50	16	68	12	18	<0.001
• Management	43	17	45	15	2	0.044
Procedure steps score	46	23	67	16	21	<0.001
Technical skills score	60	18	71	17	12	<0.001
Trauma Readiness Index	50	12	64	10	14	<0.001
Scores represent the percentage of idealized expert surgeon performance skills found in surgical trainees.						

6.6: Discussion of Results:

6.6.1: Major Findings:

The interim analysis gave preliminary validation to IPS performance metrics for assessment of vascular control procedures. Since vascular exposure procedures are used to stop bleeding it is reasonable to expect that more rapid vascular control will reduce blood loss in trauma patients. It is therefore of note that ASSET training reduced time to successful vascular control by one third. The time to perform each procedure was included as component of the TRI. Not surprisingly, knowledge of the local anatomy of each procedure closely correlated with decreased time to perform the vascular exposures. These analyses support the use of the ASSET course to improve a surgeon's technical skills for trauma.

Technical skills improved by 12 percent following the ASSET course. Since such technical skills are not specifically taught during the course and are normally acquired through years of training and experience, that the improvement seen in this assessment reflects an improvement in anatomic and procedure-specific knowledge that allowed surgeons to complete each procedure more quickly and confidently. This illustrates the complex nature of surgical skills and the overlapping influence of knowledge and technique.

The Trauma Readiness Index also includes additional knowledge management assessment focusing on disease processes such as haemorrhagic shock, ischemia reperfusion injury, along with patient management knowledge to include damage control resuscitation. These knowledge questions were categorized as patient management knowledge. Such knowledge, which is normally acquired through diligent study during the course of surgical training, was not taught nor was it improved by the ASSET course training intervention.

Important to this assessment method was the selection of three vascular procedures to represent overall trauma-related knowledge and technical skill. Although management of critically injured patients requires a wide variety of skills, the three vascular exposure procedures were selected because they are performed with relative infrequency in trauma patients and may therefore represent a fairly advanced level of trauma-specific skill, while at the same time requiring certain technical skills that are common to all types of vascular control manoeuvers. Procedure-specific checklists have been developed for many procedures, and share the common weakness that a separate checklist is required for each procedure and the quality of performance is not assessed (171). The procedure-specific checklists was included as an important component of the Trauma Readiness Index because it is imperative to ensure that the ultimate objective of each vascular control procedure is evaluated as an endpoint. Further, it is not necessary to specifically evaluate every possible vascular control manoeuver, but rather selection of representative procedures should provide an adequate representation of surgical performance. The implementation of this IPS assessment method is feasible and was reasonably cost effective (72).

6.6.2: Trauma Readiness Index (TRI):

The educational impact of training using the ASSET course was captured with the Trauma Readiness Index for trauma specific vascular exposure skills, detecting improvements in anatomic knowledge, completion of specific procedure steps, and surgical technical skills. The Trauma Readiness Index may also be a valuable tool for assessing knowledge gained through the course of residency or pre-deployment training for surgeons. The Trauma Readiness Index surgical performance assessment method was modelled after previously developed surgical skills assessment tools,(11, 12, 70, 111, 172) and incorporates a variety of assessments to achieve an overall measurement of knowledge and skills important for management of trauma patients, including knowledge questions, and procedure-specific checklists, that are based on observation of expert performances. The Trauma Readiness Index provides an objective assessment of a surgeon's readiness to perform trauma resuscitation and surgical procedures, in particular control of extremity haemorrhage. The tool is limited in its ability to assess nontechnical skills important in team management and performance in a potentially chaotic trauma resuscitation environment. The evaluation metric scores, including the Trauma Readiness Index, show no floor or ceiling effects suggesting utility to test adequacy of surgeon's performance with different levels of expertise. As others have found (70), capturing the full range of surgical performance, from novice to expert, should include the use of global rating scales. Such global rating scales evaluate the quality of overall technical skills that are not specific to any particular procedure, capturing skills such as proper handling of blood vessels and economy of movement. An experienced evaluator is required to assess such skills; certainly an experienced surgeon of the same specialty will be able to perform such an assessment; however it is likely that properly trained evaluators, including non-surgeons, will also be able to accurately assess a surgeon's technical skills using the validated skills metrics. Both physician and anatomist evaluators were trained to assess surgeon performance. When evaluations were compared there was no difference in either the anatomist or physician IPS or GRS ratings, so the mean values were used. The fresh cadaver has limitations in realism and fidelity that may have impacted the performance of the technical skills and their assessments. However studies conducted in the operating room during elective surgery, such as PBA's are also fundamentally different to emergency vascular exposure and control procedures carried out in a trauma patient resuscitation setting under the stressors of time pressure, uncertainty (the injury site, extent and how recent) as well as systems and team interactions that can be unfavourable and may have a significant impact on the quality of a surgeon's performance of technical skills.

6.6.3: Lessons Learned from Interim Analyses:

During data collection for the first 8/40 surgeons enrolled, paper and pencil data collection was used as the Mobile App was not completed. We had some missing data which we had to collect after discovery by review of audio video records. This was tiresome and added considerably to the workload. When more surgeons were subsequently enrolled and data collection was completed on the mobile App, no data collection fields were missed. The IPS metric could become a powerful tool, even a benchmark for traumatized vessel exposure if suitably validated. The initial IPS analysis in the first 12 surgeons (173) looked straightforwardly at IPS. No considerations of looking at errors or timing of procedures was considered, although this preliminary analysis suggested that both critical errors (e.g. puts vessel loop around incorrect structure) and surgery duration (e.g. takes 20 minutes or longer without identifying the vessel that is meant to be haemorrhaging) could be fruitful to show benefit from ASSET training.

6.7: Conclusion from Interim Analyses:

The important conclusion was that the Individual Procedure Score (IPS) was a novel and potentially useful metric, but IPS still needed more testing in a larger population. The interim analysis of a trauma-specific metrics showed the IPS performance assessment tool was valid and useful for assessing performance of three vascular control procedures. ASSET training reduced time to vascular control by one third. A Data Dictionary was established to allow consistency in data definitions (See Appendix II). The Trauma Readiness Index detected improvements in anatomic knowledge, completion of specific procedure steps, and surgical technical skills after training with a 1-day course. This Trauma Readiness Index assessment method could be used in skills courses, general surgery residency, trauma fellowship, or military pre-deployment training to show competency. Future applications will include assessing specific skills acquired during the course of residency training, assessing military surgical readiness, and quantifying skill degradation with time since training. A benchmark metric for trauma procedural skill would be useful for surgeons about to be deployed, for training programs to assess the benefits of trauma surgical rotations and for these vascular exposure skills that are core principles of surgery applicable to other operative procedures. Having shown that the IPS and TRI metrics could discriminate between expert and untrained resident performance using unbiased blind video review, prospective testing before and after ASSET Training was now warranted. Chapter 7 will now show the results of prospectively testing performance before and after ASSET training in a cohort of 40 PGY 2-6 surgical residents (for a summary of the entire first part of this Thesis, please see Table 6.5).

Table 6.5: Summary of Phase I of this Thesis

The Rationale for examining vascular exposure and control procedures because haemorrhage is the most frequent early cause of preventable death following trauma was established in **Chapter 1.**

The background Literature searches in **Chapter 2** and **Chapter 3** identified a lack of validation of training benefit and the variability of existing open surgery skills courses, and the need for a benchmark metric for open surgical skills for trauma.

Chapter 4 described the methods of going about the study and the considerations made in the design and analysis to maximize the robustness of the findings.

In **Chapter 5** a preliminary blind testing of Group 1 expert and untrained resident surgeons showed good inter-rater reliability in some of the metrics

Chapter 6 demonstrated a 'proof of concept' that robust data can be obtained to discriminate the effects of skills training and to show the components of the training that were most beneficial. Such details will allow future training interventions to focus on these components.

Chapter 7: Testing Surgeon Performance Before and After Training.

7.0: Overview of Chapter 7:

Chapter 7 describes Phase 2 of the Thesis effort in which testing before and after training was used to validate the IPS metric and potentially fill the trauma skills training measurement gap identified in the literature review. After the preliminary analyses in 12 resident surgeons, surgeon enrollment was now able to progress rapidly, limited only by the scheduling of busy surgeons and a busy cadaver laboratory. Chapter 7 will determine if the metrics for trauma-related technical and non-technical procedural skills can validate the benefits of the ASSET course and test the hypothesis that the individual procedural score (IPS) will quantify the training benefits of the ASSET course.

7.1: Use of ASSET Training as a Vehicle to Test Metrics:

Chapter 7 presents evaluation of ASSET training with the aim of correcting the lack of a benchmark surgical performance metrics against which to compare trauma surgeon performance and identify relative competence for vascular exposure and control in haemorrhaging trauma patients. The methods to examine surgical performance and to develop the performance metrics were informed by the first three chapters and are described, together with their limitations in Chapter 4. Chapter 5 demonstrates the lack of surgeon self-recognition of performance and the need for objective data gathering in a standardized manner to identify deficiencies in technical and non-technical skills acquisition. ASSET training is used as a vehicle to test whether untrained (2- 6th year of training) surgical residents can improve performance of technical and non-technical skills as judged by the IPS metric, and GRS developed in preliminary testing.

7.2: Chapter 7 Aims:

Aim 1 of Chapter 7 is to determine whether untrained 2- 6th year surgical residents can improve performance of technical and non-technical skills for rarely performed vascular exposure and control procedures.

Aim 2 of Chapter 7 is to test the hypothesis that an individual procedure score (IPS), will validate the benefits of ASSET training among residents performing combat-relevant upper and lower extremity emergency vascular exposure and control procedures.

7.3: Methods:

Study description and an enrolment invitation letters were sent to Directors of nearby surgical training programs. Surgeon recruitment was relatively easy, because of funding to provide a financial incentive (for study participation, ASSET Course participation and travel) and the proximity of multiple surgical training programs to the Maryland State Anatomy Board, where cadavers were available. The 13 surgical training programs from which the 40 resident/fellow PGY 2-6 surgeons were enrolled are as follows, number of participants in [brackets]. Johns Hopkins University [13], Thomas Jefferson University, Philadelphia [4], Abingdon Memorial Hospital [4], Walter Reed, Army [3] , York Hospital, York, Pennsylvania [3], Sinai Hospital, Baltimore [3], University of Pennsylvania [2] , Mercy Catholic Medical Center (Darby, PA) [2], Albert Einstein, Philadelphia [2], Pinnacle Health, Harrisburg Pennsylvania [1] , George Washington University [1], Howard University [1], University of Maryland [1].

The surgeons were paid \$300 when they returned for Post –ASSET Course evaluation, and their ASSET Course Registration (\$500) was also paid. Travel (and where needed, accommodation) was provided for the 3 visits, which were completed within 4 weeks of pre-ASSET enrollment. ASSET Courses were conducted at regular intervals, independently of the Pre- Post- ASSET Course evaluations, so there was no training bias involved in the ASSET Course Instructors. As ASSET training is now considered an important part of surgical training programmes for which the programmes normally would cover the costs, there was an over-subscription to study enrollment and first come, and first enrolled was the process. One surgeon failed to return after the ASSET course, so it was easy to enroll a replacement.

On arrival at the cadaver laboratories, participants completed a demographics questionnaire (years in residency, numbers of upper and lower extremity vascular procedures performed), then performed axillary (AA), brachial (BA), and common, superficial and profunda femoral artery (FA) vascular exposure procedures on unpreserved cadavers guided by the standardized scripts. The script included a patient scenario, patient management knowledge questions, and marking of the planned surgical incision, followed by completing the indicated procedure. To ensure capture of all procedures, responses to questions, and surgeon commentary on their actions, each research subject was instrumented with a head mounted laser-directed head camera (Looxcie LX2 Looxcie, Inc. Sunnyvale, CA 94089) and headset boom microphone (Clear-com CB222/Clear-com CC-95 headset Clear-Com, LLC, Alameda, CA 94501). Audio and video recordings were made from ceiling-mounted microphones (Shure MX202 Ceiling Mic Shure Inc. Niles, IL) and pan-tilt zoom (PTZ) cameras (Vaddio Ceiling View 70 PTZ Camera Vaddio, Minnetonka, MN 55305) at each location, and wall-mounted overview cameras at each of 6 instrumented cadaver table locations.

7.4: Metrics Development:

The performance evaluation metrics for three upper and lower extremity vascular control procedures were developed and underwent preliminary validation as described in Chapter 6. The Individual Procedure Score (IPS) was based on responses to knowledge, anatomy, and patient management questions posed in the script and observation of technical and non-technical skills during cadaver surgery. The time from skin incision to passage of a double vessel loop around the identified vessel was recorded (Table 7.1). As shown in the example scripts (Appendix II), responses included yes/no answers for knowledge questions or checklists for procedural steps and Likert scales for surgical technical skills. Subjective global ratings were scored for comparison to IPS. GRS were not included in the IPS score. Scoring of IPS was determined by consensus expert input during the Delphi consensus discussion described earlier. Experts designated each response as an essential response or action (2 points, bold in the script), additional knowledge (1 point), or error (2 points if uncorrected and 1 point if corrected, red in the script). A comprehensive score, the sum of each procedure IPS, called the Trauma Readiness Index (TRI) was used to describe the overall surgeon competence to stop haemorrhage.

Table 7.1: Five components of the Individual Procedure Score (IPS) calculations are knowledge, anatomy, management/indications/procedural steps, technical skills and time to complete the procedure. Table 7.1 shows where these data are obtained from the script. Details of each item in the Table 7.1 e.g. technique points and expert discriminators can be found by reference to the scripts in Appendix II Table 7.1 shows the commonalities of IPS across Axillary Artery, Brachial Artery, and Femoral Artery scripts.

	Knowledge	Anatomy	Management/ Indications	Procedural Steps	Technical Points
What structures could be injured?	✓	✓			
What are the physical findings? (AA and FA only)	✓		✓		
Are there any additional studies to be performed?	✓		✓		
What is your plan for the patient?	✓				
What interventions are important/ are there any systemic consequences of delayed diagnosis? (FA only)	✓		✓		
How would you position and prep the patient for surgery?	✓	✓			
How do you plan to gain control of the bleeding vessel? (BA only)	✓		✓		

What are the landmarks?		✓		✓	
Knowledge	Anatomy	Management/ Indications	Procedural Steps	Technical Points	
Performance checklist/ time to complete procedure.		✓		✓	
Technique Points.					✓
Expert Discriminators.					✓
What are the consequences of ligating the artery?	✓	✓			
What are the pitfalls or common errors when performing this procedure?	✓	✓			

7.5: Results:

7.5.1: Surgeon Demographics:

Within a 9 month interval, 41 surgical residents and fellows were enrolled. Two co-located evaluators completed 40 evaluations before and within two weeks after completion of the 1-day ASSET course. One surgeon was evaluated on the pre-training procedures and completed the ASSET course but did not return for follow-up and was excluded from the study. The 40 participants who completed all study evaluations (23/40 were male) were mean ± standard deviation [SD] age 30.7 +/- 5.7 years, had residency training of 3.5 +/- 1.2 years (range 2- 6 years) and had performed 105 +/- 48.9 previous trauma patient treatments or evaluations.

7.5.2: Inter-Rater Reliability and Consistency by ICC:

Among 4 separate evaluators, (two before training and a different two after ASSET training), the ICC for IPS for AA was 0.91 with confidence interval (CI) 0.86-0.95. For FA the ICC was 0.94 (CI 0.90- 0.96) and for BA 0.84 (CI 0.75- 0.90). The ICC for the individual components of the IPS for the three procedures is shown in Table 7.2. These ICC are excellent to outstanding. The linear mixed model analysis showed no evaluation difference between physician or non-physician anatomist evaluators.

Table 7.2: Intra Class Correlation Coefficients (ICC) for components of Individual Procedure Score (IPS) and for IPS for each of Axillary, Brachial, and Femoral Artery by pairs of evaluators before and after training.

	Axillary Artery	Brachial Artery	Femoral Artery
IPS	*0.91*	*0.84*	*0.94*
Anatomy	*0.89*	*0.78*	*0.91*
Knowledge	*0.74*	*0.67*	*0.77*
Management	*0.71*	*0.58*	*0.82*
Procedural Steps	*0.97*	*0.89*	*0.95*
Landmarks	*0.90*	*0.51*	*0.76*
Time	*0.97*	*0.98*	*1.0*

7.5.3: IPS Evaluation of Surgeons Before and After ASSET Training:

Using IPS evaluation of participants before and after training, significant improvement ($p < 0.001$) occurred for each of the 3 artery exposures (Fig 7.1). Note that no floor or ceiling effect was observed in the IPS metric within the range of resident performance evaluated. The TRI showed a 28 % increase in scores for overall performance in exposure and vascular control for the three procedures, including a 43 % increase in the anatomy component and a 57% increase in the procedural steps component.

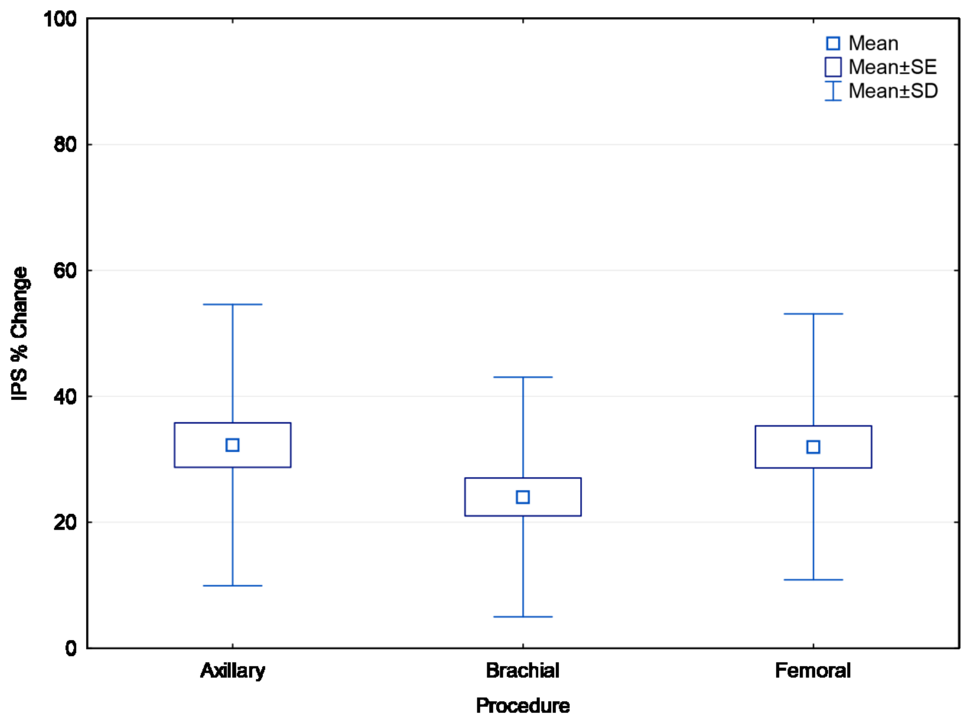


***Figure 7.1**: Box and whisker plots of percent change in Individual Procedure Score (IPS) from baseline before training to after training (n=40) for Axillary, Brachial and Femoral artery exposures (box: mean±1SE; whisker: mean: mean±1SD). Percent (%) IPS change with training is shown on Y axis for each of 3 procedures shown on the X Axis.*

Details of these changes for TRI and each procedure are shown in Table 7.3. A comparison of IPS score components of anatomic knowledge and surgical performance before and after training shows that all these metrics were significantly different (p <0.001) with the exception of management components (which were not part of the training) (Table 7.3**).** When IPS data related to procedure time, landmarks, incision placement, correct artery identification and successful vascular control (the essence of surgical haemorrhage control) are considered together for axillary, brachial and femoral arteries these components of IPS were all significantly (p<0.001) improved with ASSET training. Time to complete the AA, BA, FA vessel exposure and control decreased significantly (p< 0.001) by a mean of 1.9- 3.1 minutes (Table 7.4). These data support ASSET training as a mechanism to increase performance in vascular exposure and control.

Table 7.3: Comparison of Individual Procedure Score (IPS) components before (Pre) and after (Post) training for Axillary, Brachial, Femoral artery exposures and a pooled trauma vascular readiness index using linear mixed models. Note all performance metrics are significantly different after training (p< 0.001) with the exception of Management components (not part of training). TRI= comprehensive IPS for axillary, brachial and femoral arteries = Trauma vascular readiness index

		Pooled Vascular mean ± SD	Axillary Artery mean ± SD	Brachial Artery mean ± SD	Femoral Artery mean ± SD
Overall Knowledge	Pre	0.5 ± 0.01	0.44 ± 0.02	0.62 ± 0.03	0.5 ± 0.02
	Post	0.56 ± 0.01	0.5 ± 0.02	0.69 ± 0.02	0.56 ± 0.02
	diff	0.06**	0.06**	0.06**	0.06**
Anatomic	Pre	0.46 ± 0.02	0.44 ± 0.03	0.57 ± 0.03	0.38 ± 0.07
	Post	0.71 ± 0.02	0.69 ± 0.02	0.74 ± 0.03	0.76 ± 0.06
	diff	0.25**	0.24**	0.17**	0.39**
Management	Pre	0.42 ± 0.02	0.35 ± 0.02	0.59 ± 0.03	0.43 ± 0.02
	Post	0.44 ± 0.01	0.37 ± 0.02	0.58 ± 0.03	0.46 ± 0.02
	diff	0.02	0.02	-0.01	0.03*
Procedural Steps	Pre	0.39 ± 0.03	0.43 ± 0.04	0.49 ± 0.04	0.3 ± 0.05
	Post	0.65 ± 0.02	0.73 ± 0.03	0.67 ± 0.03	0.59 ± 0.05
	diff	0.26**	0.3**	0.18**	0.29**
IPS/TRI	Pre	0.48 ± 0.01	0.46 ± 0.02	0.56 ± 0.02	0.45 ± 0.02
	Post	0.63 ± 0.01	0.61 ± 0.02	0.69 ± 0.02	0.6 ± 0.02
	diff	0.15**	0.15**	0.13**	0.15**

Significance of difference demarked as α=0.05: ** p< 0.001; *p< 0.05

Table 7.4: Objective components of Individual Procedure Score assessing steps in the vascular exposure for axillary, brachial and femoral arteries are shown, before (Pre) and after (Post) training and the difference (diff). All vascular exposure and control metrics are significantly improved with ASSET training (p< 0.001) using linear mixed model (procedure time, landmarks) and general linear mixed models for binary data.

		Axillary Artery	Brachial Artery	Femoral Artery		
		mean ± SD	mean ± SD	mean ± SD	mean ± SD	mean ± SD
Procedure Time (mins‡)	Pre	9.7 ± 0.89	10.9 ± 1.05	15.8 ± 1.02		
	Post	7.2 ± 0.81	8.9 ± 0.97	12.6 ± 0.96		
	diff	-2.5**	-1.9**	-3.1**		
Landmarks	Pre	0.34 ± 0.06	0.5 ± 0.06	0.53 ± 0.05		
	Post	0.73 ± 0.05	0.63 ± 0.05	0.76 ± 0.05		
	diff	0.39**	0.13**	0.23**		
Adequate Incision ¥	Pre	0.25 ± 0.05	0.76 ± 0.08	0.36 ± 0.1		
	Post	0.82 ± 0.05	0.97 ± 0.08	0.77 ± 0.09		
	diff	0.57**	0.21**	0.41**		
				SFA†	PFA†	CFA†
Correct Artery ID ¥	Pre	0.57 ± 0.08	0.62 ± 0.09	0.62 ± 0.09	0.48 ± 0.1	0.47 ± 0.1
	Post	0.96 ± 0.07	0.95 ± 0.08	0.95 ± 0.08	0.82 ± 0.09	0.85 ± 0.09
	diff	0.39**	0.32**	0.33**	0.34**	0.38**
Controls Arteries ¥	Pre	0.36 ± 0.05	0.63 ± 0.1	0.59 ± 0.09	0.46 ± 0.1	0.42 ± 0.1
	Post	0.84 ± 0.05	0.88 ± 0.09	0.92 ± 0.08	0.81 ± 0.1	0.82 ± 0.09
	diff	0.47**	0.26**	0.33**	0.36**	0.4**

†CFA: Common Femoral Artery; SFA: Superficial Femoral Artery; PFA: Profunda Femoral Artery

¥ Binary data analyzed with General Linear Mixed Model

Significance of difference demarked as α=0.05: ** p< 0.001

‡ Minutes calculated to the 0.25 minute

7.6: What Vascular Exposure Steps Improved with ASSET Training?

Pre- versus post- training identification of correct anatomic surface markings, skin incision, technical skills and procedural steps showed significant improvement for AA, BA, and FA exposure (Figure 7.2 and Table 7.4). Correct placement of surface landmarks and skin incision occurred more often for all 3 procedures after ASSET training (Figure 7.4 all differences $p < 0.001$). When these results are graphically represented as vectors of correct vascular control procedural steps or change before and after training (Figure 7.3 *Panels A and B*) several potentially interesting training requirement data are revealed. Some surgeons were performing well as judged by landmark and procedural steps even before ASSET training. Two surgeons showed no improvement with training (Fig 7.3).

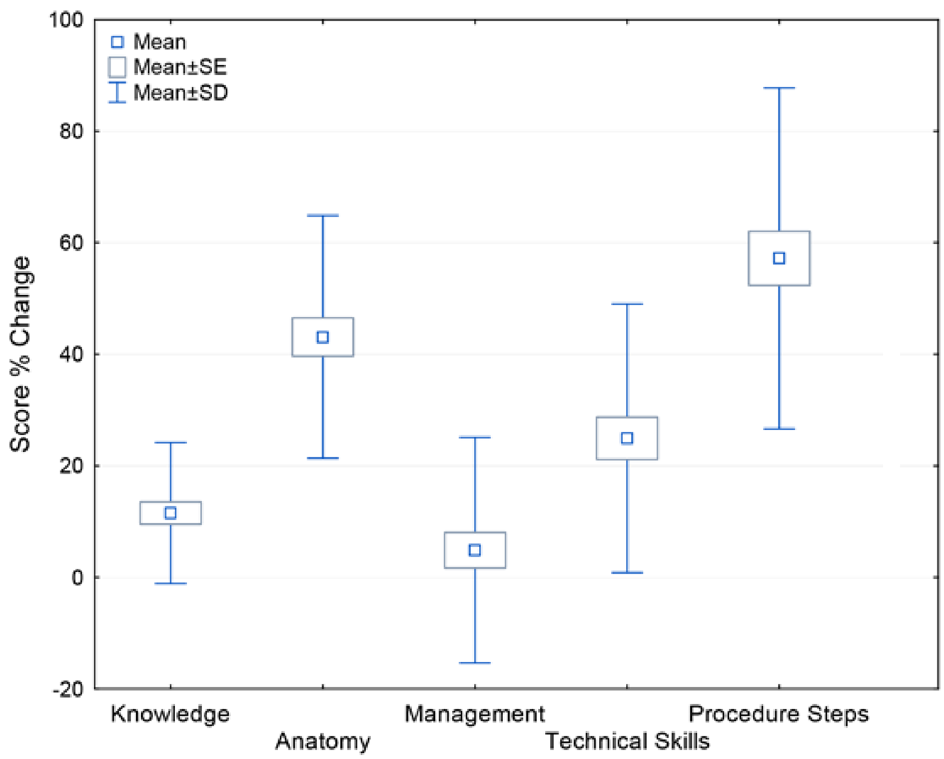


Figure 7.2: *Box and whisker plots of percent change in component scores and in the vascular trauma readiness score (Vascular TRI) from baseline before training to after training (n=40) for*

combined vascular exposures (box: mean±1SE; whisker: mean: mean±1SD). % IPS Score change from pre-ASSET Score is shown on the Y Axis for each procedure shown on the X axis.

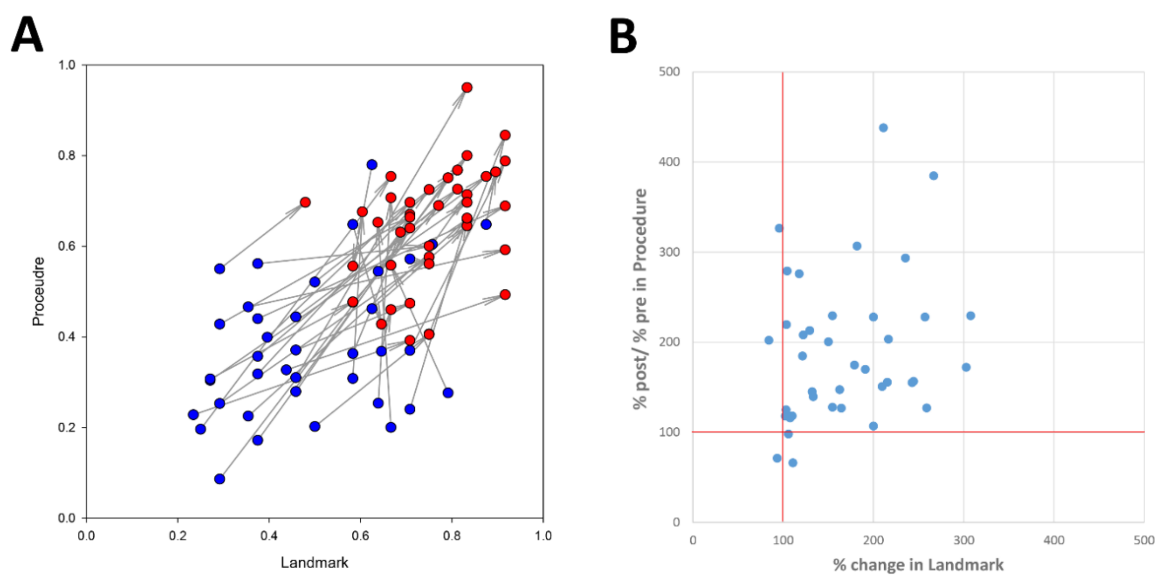


Figure 7.3: *Panel A: Plots of Pre -ASSET (blue circles) and Post-ASSET (red circles) showing the aggregated change in correct vascular procedural steps and landmarks, for axillary, brachial and femoral arteries with training. Note that several surgeons already had both procedural steps and landmark scores in excess of 0.5 before training, and two surgeons showed a decrease in landmark score but this was accompanied by an increase in procedural steps score with training. Panel B: Percent (%) change in procedure and landmark scores with ASSET training. Red axes represent the no change thresholds. Note two surgeons who showed no change with training.*

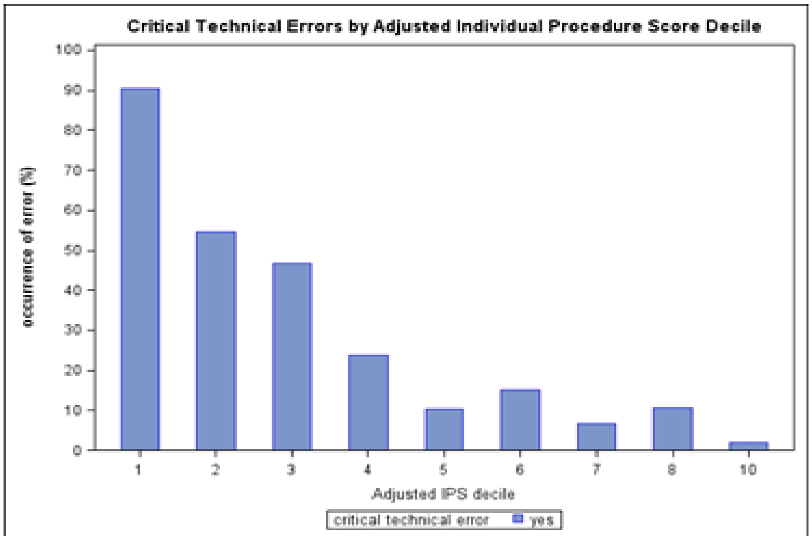


Figure 7.4: *When error occurrence on Y axis is plotted against Adjusted IPS (Adjusted IPS metric has no errors or time errors included) a linear increase in errors occurs when adjusted IPS goes below about decile 6 (60%) of the resident surgeon cohort Inividual Procedure Score.*

7.7.1: Predicting Errors & Errors in Recognition of Upper and Lower Extremity Vasculatures Before and After ASSET Training:

When error occurrence is plotted against Adjusted IPS an exponential increase in errors occurs when adjusted IPS goes below about decile 6 (60%) (Figure 7.4), so this benchmark could be used to identify those surgeons who should undergo remedial intervention.

When recognition of critical technical errors was compared, there was identical critical error recognition between co-located evaluators and blind video reviewers for the AA, BA, and FA procedures. In addition, video reviewers and co-located evaluators were in total agreement (p=1.0) for error recognition and surgeon self-correction among AA, BA, and common FA exposure procedures.

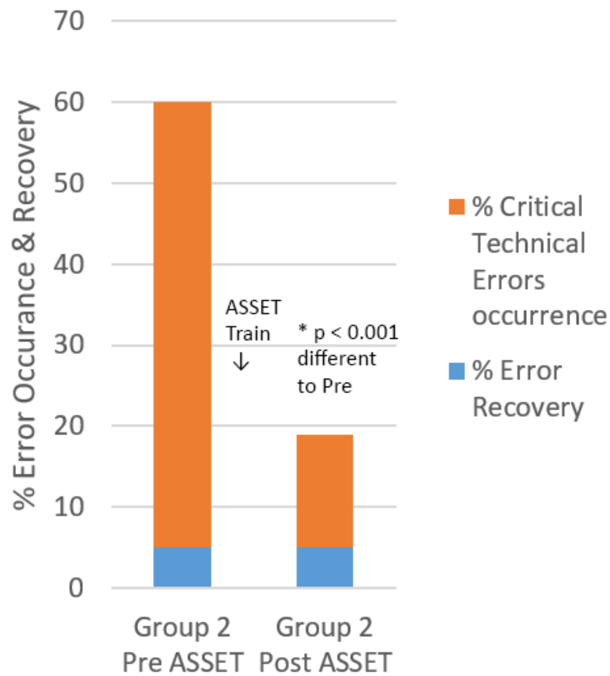


*Figure 7.5**:** Left Panel: Comparison of critical errors (e.g. passed vessel loop around median nerve instead of brachial artery) in 40 residents and Fellows Pre-Post ASSET training Red histogram represents uncorrected errors, Blue histogram represents errors that were self-recognized and successfully corrected. There was a significant (p <0.001) reduction in errors in the 40 surgeons as a result of training and a significant increase in error self-recognition (p <0.025) with the one-day ASSET training.*

Figure 7.6: Left panel: improvement in IPS Procedural Skill plotted as a function of initial score. The higher the initial IPS the less the percent improvement is. Curve intersects at 0.6 and predicts scores greater than this do not improve with training. Right panel: improvement in correct landmark identification scores shows an intersect at 0.8. Higher intersect than procedural steps suggests training in correct landmarks maybe the most valuable training intervention. These data may be sufficient to predict how "valuable" training will be and what sort of training is needed.

7.7.2: Clinical Year of Residency Data:

When all these results are analysed by clinical year of training (2nd - 6th year) no significant difference ($p = 0.2$) in IPS among these surgeons is noted, with the exception of a significant difference in management ($p = 0.003$) and knowledge ($p < 0.001$) for AA anatomy ($p=0.03$) and procedural steps ($p=0.008$) for BA anatomy and knowledge (both $p<0.001$) in TRI.

7.8: Correlation of IPS with Global Ratings:

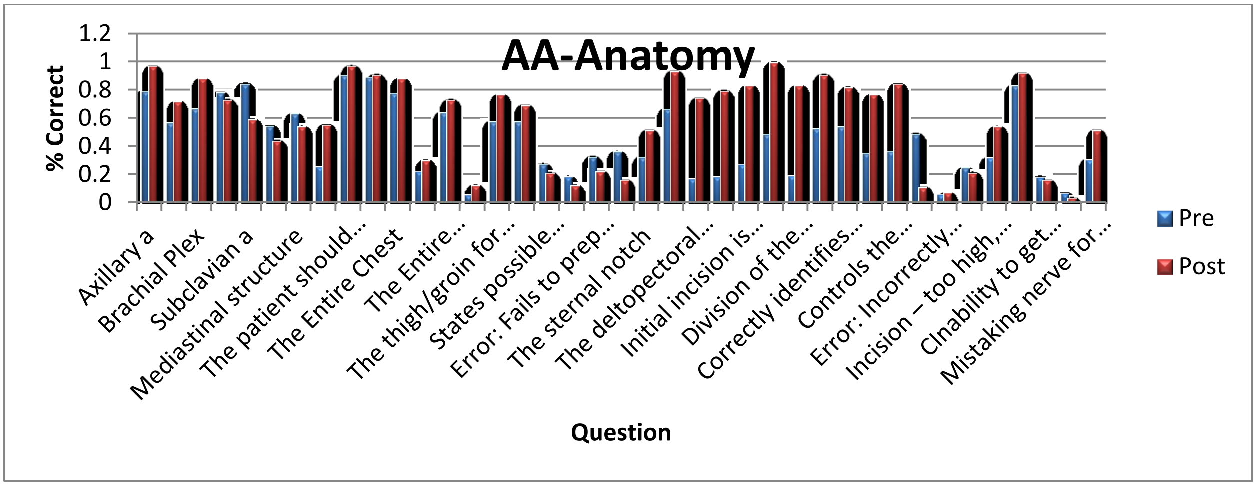
In addition to the IPS, evaluators gave one independent global rating of surgeon performance which subjectively summarized the evaluators' overall impressions of the surgeons' knowledge and skill, and four global ratings evaluating management, anatomy, technical skills and readiness to independently perform the procedure. Table 7.5 shows the Pearson's Correlation coefficients (r) values of IPS to an overall evaluator global rating of surgeon performance and the four other global ratings. IPS for AA, BA, FA and the TRI are shown pre- and post- ASSET training. The IPS was significantly different ($p < 0.001$ by Fisher's Z transformation) from the subjective overall global ratings of surgeon performance before and after training for all procedures with the exception of overall global evaluator rating to perform FA exposure after ASSET training. All of the four global ratings evaluating management, anatomy, technical skills and readiness to independently perform the procedure were different ($p < 0.001$) from the IPS (**Table 7.5**). These data, considered along with the results in Table 7.3 and Table 7.4 support the use of IPS as a metric for competency in vascular exposure and control in comparison to the five subjective global ratings.

Table 7.5: Pearson Correlation coefficients (r) for Global Ratings and Overall Evaluator Ratings before (Pre) and after (Post) training and Individual Procedure Scores (IPS) for performance of axillary artery (AA), brachial artery (BA) and femoral artery (FA) vascular exposure. The Global ratings and overall evaluator ratings were subjective independently scored global ratings (overall performance, management, anatomy, technical skills and readiness to independently perform the procedures). Italics show p < 0.001 [α=0.05] identifying that all subjective global ratings except FA Post are significantly different than the checklist metrics included in IPS.

			Global ratings			
		Evaluator Rating	Global Management	Global Anatomy	Global Technical skills	Global Readiness
Vascular TRI	Pre	*0.67*	*0.56*	*0.62*	*0.67*	*0.59*
	Post	*0.41*	*0.47*	*0.69*	*0.63*	*0.38*
Axillary IPS	Pre	*0.71*	*0.31*	*0.76*	*0.39*	*0.67*
	Post	*0.56*	*0.51*	*0.64*	*0.60*	*0.45*
Brachial IPS	Pre	*0.46*	*0.45*	*0.60*	*0.73*	*0.55*
	Post	*0.52*	*0.49*	*0.73*	*0.61*	*0.50*
Femoral IPS	Pre	*0.83*	*0.58*	*0.79*	*0.64*	*0.78*
	Post	0.17	*0.44*	*0.64*	*0.63*	*0.42*

7.9.1: Item Analysis of Answers to Individual Questions Using an Example of Axillary Artery (AA):

Item analysis of each question in the IPS score was performed for each of the three vascular exposure and control procedures in 40 surgeons. The purpose of this analysis was twofold, i) to ensure that all questions were in use; ii) to allow at some future time, a revision of IPS and a revision of the current scoring and question weighting. As can be recognized from the responses to questions asked in the axillary artery (AA) exposure shown in Figure 7.5, some questions relating to landmarks procedural steps and incision placement showed large differences resulting from training (red histograms = after training). Other questions related to positioning the patient and to skin prep show less difference with training. Some questions everyone answered correctly irrespective of training status. In the lower panel of Fig 7.5, all components of AA procedural steps were more frequently correct, and errors did not occur after training.



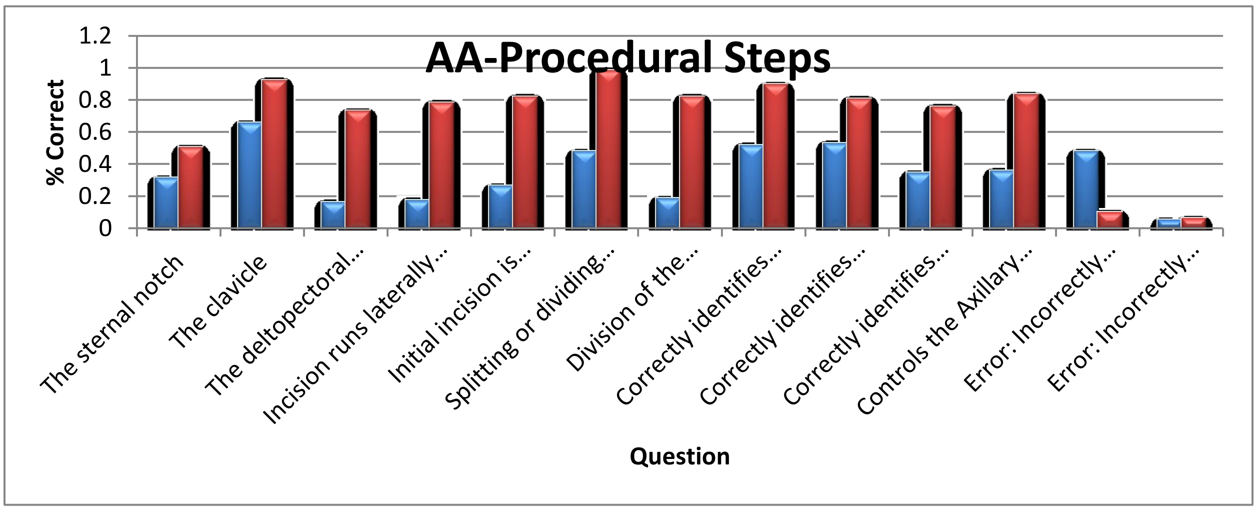


Figure 7.7: Top Panel: *Shows item analysis of 24 questions answered correctly for AA Anatomy (Top Panel) in 40 surgeons. Complete script for AA is in Appendix II. Blue histograms represent Pre ASSET training responses among 40 surgeons and Red histograms represent the responses by the same surgeons after ASSET training. In* ***Bottom Panel:*** *Correct Procedural Steps in 13 evaluation steps related to landmarks and incision placement, AA vessel identification in same 40 surgeons as Top Panel. Blue represents Pre-ASSET and Red histograms after taking the ASSET course.*

7.10: Self-Reports Before and After ASSET Training:

Self-reports of confidence in performing upper and lower extremity traumatic injury procedures were obtained before and after ASSET training. Among 12 of the 40 study participants the questions in the self-report surveys were obtained four times: before and after the pre-ASSET assessment and again before and after the post-ASSET assessment.

After ASSET training, self-reported confidence increased significantly ($p < 0.001$). On a Likert scale of 1 (= no) to 5 (= complete), all participants reported scores 4 or greater for upper and lower extremity trauma for understanding anatomy and comfort level for exposing major vasculature, compared to scores of less than 2.5 before the ASSET training. Figure 7.6 shows pre- and post- evaluation confidence results for 12 participants who completed these evaluations both before and after ASSET training. Overall, no differences in self-confidence were reported pre- and post-assessment <u>before</u> ASSET training ($p = 0.2$), however, some surgeons reported persistent decrease in confidence post-evaluation before ASSET training for selected procedures, that is, the participants did not initially realize how much they did not know about these procedures(47). However after ASSET training, surgeons gave the highest Likert confidence score for these same procedures (Figure 7.6).

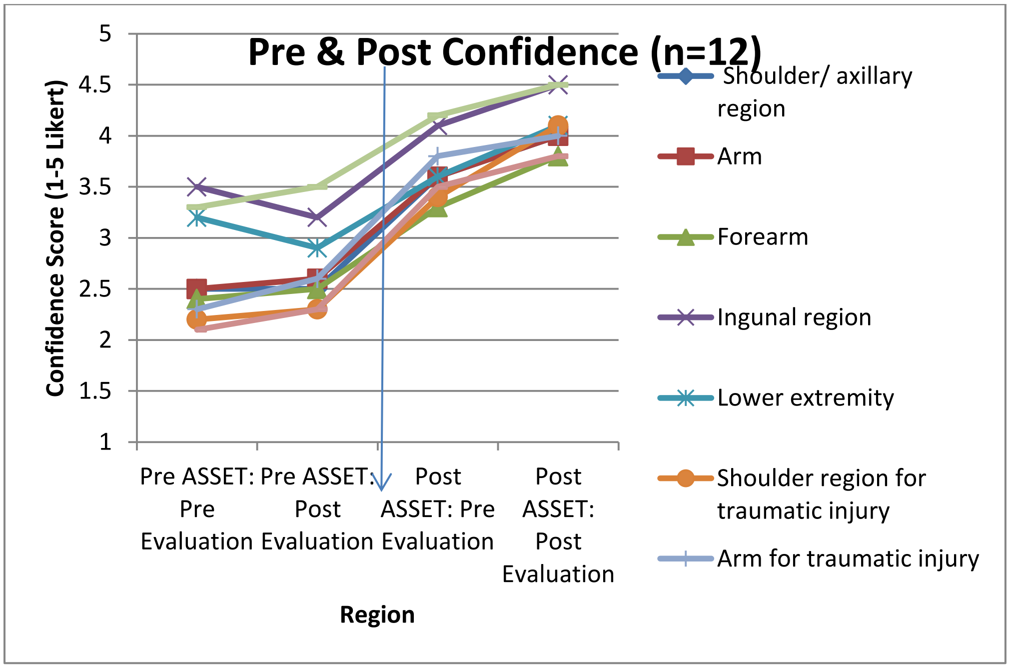


Figure 7.6: *In 12 surgeons , self- reported confidence in performing upper and lower extremity vascular control procedures were obtained four times. These are plotted before and after the initial study evaluations and then before and after Advanced Surgical Skills Exposure for Trauma (ASSET) training. For lower extremity procedures confidence appeared to fall after the first evaluation before ASSET training.*

7.11: Discussion of Findings:

Many recent reviews have detailed the state of observational tools for assessing surgeon performance, competency, technical skills, psychomotor skills, and skills acquisition measurement (65-69, (144, 174-176). However, none of those measures are specific for trauma-related emergency surgical procedures, which have unique temporal and management criteria. Individual surgeon performance is not measured systematically or specifically during residency training (177). The present study of trauma-specific vascular procedures shows that correct identification of surface landmarks, incisions and procedural steps can be documented and the IPS increased for vascular exposure and control after ASSET training. The IPS metric documents competency in vascular control procedures. The benefit of ASSET training was shown to occur regardless of clinical year of training.

An important part of surgeon evaluation is the consistency and reliability of evaluators. Conscious or unconscious biases are present in many types of performance assessments, and ensuring that any assessment tool includes rigorous well defined parameters is critical. The consensus development of the IPS metric identified specific characteristics and steps that a trained evaluator can implement, with limited room for unconscious bias. Indeed, when we assessed metrics scores between evaluators, the inter-rater reliability is high and consistent. Of particular note are the near-perfect ICC evaluator agreement on components of IPS including procedural steps, landmarks (except for BA) and time. BA had the lowest among all ICC coefficients for surface landmarks, and the lower evaluator agreement may reflect the absence of bony landmarks and mobile soft tissues associated with BA skin incision. Correlations of the subjective global ratings and objective metrics contained within the IPS are not as robust as the ICC agreements suggesting that the objective scoring method is more consistent and reliable than the traditional subjective evaluation method. We concluded that improved knowledge of local anatomy resulted in correct incision placement using surface landmarks taught in the ASSET course. Anatomic structural recognition and specific procedural steps were the key knowledge gained during the 1-day training course. As such, ASSET training may help accelerate acquisition of emergency surgery specific skills to compensate for shortened training hours, for military surgeons preparing for war or whenever just-in-time training is necessary. Anatomic knowledge, including surface landmarks and incision placement, although accounting for only some of the total IPS score accounted together with procedural steps for a disproportionate amount of ASSET training improvements in the IPS metric and are key to successful trauma surgeon training. Focused training in surgical vascular anatomy can result in very significant performance improvements after a single day of training, however the sustained impact of such training requires further study.

The increase in error occurrence with decrease in adjusted IPS score seen in this study is further validity evidence for the robustness of the IPS metric in capturing multiple facets of surgeon performance. Together with the GRS they strengthen the belief that IPS captures multiple dimensions, not just technical skills. Further convergent validity of IPS is provided by the blind video analysis described in Chapter 8.

7.12: How Does This Study Compare with Others?

Many of the previously reported observational tools measuring surgeon technical and non-technical skills were developed and validated on simple part-task-trainer simulators (knot tying, laparoscopic peg board movement etc.) (178, 179) the fidelity and validity of such metrics for evaluation of open surgery in the operating room is inadequate. There is very little good data describing precisely what surgeons do when performing surgery. Much of surgeon performance data is focused on team, rather than individual, surgeon performance (43, 140), (180), (70) and there is no consensus on the objective analysis of technical performance by clinicians (140). There are no benchmarks for evaluation of individual surgeon performance, nor is there agreement on how such metrics might improve clinical outcomes (43, 70, 140). In the present study, preliminary expert video recording captured recurrent and interrelated factors in communication and task performance and facilitated identification of individual, and technical constraints that characterize ASSET training. A key to development of these novel metrics was recording of expert "thinking out loud" and formally structured didactics as these experts did the selected procedures, providing a platform for measuring the complexity of individual surgeon performance. (116, 120, 123).

7.13: Strengths of Data Collection and Approach:

Use of a standardized script in which all enrolled surgeons were asked exactly the same questions and evaluated performing the procedures with the same metrics is a strength and lends consistency to this study. Surgery performed on an unpreserved cadaver is generally considered to be the 'gold standard' of surgical simulation. Video recording from both a head mounted camera and an overhead camera and use of three separate audio capture systems allowed us to capture all events along the same audio-video timeline. Use of the mobile application facilitated multiple different sequences of scripts, and ensured all evaluations were collected. Sufficient funding to support ASSET training, travel and accommodation (where needed), allowed scheduling of surgeons 3 months in advance and coordination with timing of ASSET courses. We were thus able to schedule 40 surgeons to be evaluated twice and return within 2-4 weeks of training, with only one loss to follow-up. In this study surgeons worked unassisted with no input from the evaluators, so only individual performance was evaluated.

7.14: Limitations of This Approach to Performance Assessment:

The IPS assessment method is labour and resource intensive and is specific to the procedures evaluated, although there are many commonalities with procedures to control haemorrhage from other damaged vasculature in trauma patients. Because of the cost and resource utilization of these surgeon performance evaluations, consideration should be given to use of alternative means of assessing surgeon performance that do not involve use of cadavers.

7.15: Evaluator Bias:

Evaluator bias is a factor in such studies as this one. We tried to minimize bias, by pairing trainees with different evaluators before and after training. However, we could not prevent evaluators from knowing that the surgeons had taken the ASSET course within 2-4 weeks of their second evaluation. This knowledge may have caused the differences between evaluators overall global ratings of surgeon performance and IPS before and after training. Evaluators may have been biased to (76) give higher global ratings if they knew that the participants were recently trained. Alternatively, the surgeons may have benefitted from the debriefing given at the end of each evaluation. The debriefing provides feedback on all the surgical procedures, including additional cadaver dissection and a discussion of any performance problems noted by the senior of the two evaluators and a description and demonstration of incorrect vessel identification made by the surgeon. Previous reports found that receiving feedback from an expert enhanced technical performance with regards to its overall quality, (86, 106) economy of motion, (76, 86), (106) number of errors, (76) time taken to complete task, (76) and overall quality of end-product. (74, 78). Evaluator bias is further addressed in the blind video analysis study described in Chapter 8.

7. 16: Summary Conclusions for Chapter 7:

Chapter 7 shows that ASSET Training improves performance of the majority of surgeons who took the course. Training benefitted all surgeons regardless of year of surgical residency. Correct identification of surface landmarks & incisions associated with improved vascular control performance, structural recognition during specific procedural steps, correct skin incision and surface anatomic knowledge were key points taught during a 1-day combat surgical skills training course. Scores for overall performance in exposure and vascular control increased for the three procedures, including a 43% increase in the anatomy component and a 57% increase in the procedural steps component. Global Ratings were different to IPS in assessment of surgeon performance. It therefore seems that ASSET training can accelerate acquisition of emergency combat surgery specific skills to compensate for shortened training hours, lack of these injuries in civilian practice or when just-in-time training is necessary. To further validate these findings, Chapter 8 considers whether evaluator biases could have been the cause of the evaluators finding improved surgeon performance with training.

CHAPTER 8: Assessing Impact of Bias and Convergence of Data to Validate Performance Metrics.

8.0: Overview of Chapter 8:

Chapter 8 brings together several of the analyses to solidify the evidence confirming the robustness of IPS as a metric that can evaluate surgical performance in trauma related procedures, by elimination of the bias of co-located evaluators, who knew that surgeons had received their ASSET course training. There are several limitations to the data collection techniques and understanding of evaluator biases and the scoring system used for IPS that became apparent as a result of the study described in Chapter 7. Chapter 8 examines these limitations and evaluation biases by use of video recordings to "blind" the evaluators to pre- post training performance, to assess the validity of the IPS performance metric and the impact of evaluator bias across a spectrum of high, medium and low performance. Video recordings reviewed by the blind evaluators were made at the same time as the co-located evaluators were present conducting the "real-time" evaluations. Multiple video-raters tested with inter-rater reliability and consistency can provide convergence of validity for IPS to determine whether the benefits seen in improved surgeon performance with ASSET Training shown in Chapter 7 were due to biased evaluations

8.1: Introduction:

Assessment of surgical technical skills is complicated by many factors including adequate evaluator training, occurrence of bias, pre-conception of a surgeon's ability, the subjective nature of such surgical technical performance evaluations, and an inadequate understanding of expert surgical technical skill. It is well recognized that variation in individual surgeon technical performance and surgeon volume (181) has a major impact on surgical patient mortality (112), morbidity (182), duration of surgery (183), re-operation and re-admission (184). The life versus death outcome based on surgeon performance is never more important than for emergency haemorrhage control following trauma. As described throughout the Thesis, evaluator bias is a confounder of many reports of medical education (2). The bias I am particularly concerned about in the study reported in Chapter 7 is the knowledge the evaluators gained that surgeons had taken the ASSET course. The ASSET course was coordinated through a totally different entity, The Maryland Trauma Board, although the ASSET courses were held in the same facility as my study was conducted, training was by a separate group. There was no training bias (training for the study). However, the evaluators may have been biased to score performance higher as a result of the knowledge that the surgeons had completed the ASSET course training. To avoid this bias, randomly ordered pre-, post- training video of haemorrhage control procedures was used showing images of surgeon hands performing the procedures, as described in the methods below. As haemorrhage control is a basic necessity of emergency trauma care for civilian and military surgeons, I sought to determine the validity of a procedure-specific individual procedure score (IPS) metric (185) to assess solo surgeon performance of trauma surgery technical skills for lower and upper extremity injuries included in ASSET training. Non-technical skills were not evaluated in these blinded analyses.

8.2: Chapter 8 Aims:

Aim 1 of Chapter 8 is to determine whether the benefits seen in improved surgeon performance with ASSET Training shown in Chapter 7 were due to biased evaluations. Aim 2 of Chapter 8 is to measure inter-rater reliability of blinded evaluators across the spectrum of high, medium and low performance to assess the validity of the IPS performance metric, using the criteria for methodological quality associated with the Medical Education Research Study Quality Instrument (MERSQI) and the Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) to assess study biases.

8.3: Methods:

As described in earlier Chapters, data collection occurred including audio-video data capture and scheduling of surgeon evaluations before and within 4 weeks of ASSET training. The script was identical to that used in all the studies. Specific methodological details for the blinding of video clip capture and preparation and statistical analyses are described below.

8.4: Duration of Recording and Blinding of Video Capture:

A head camera worn by the surgeon audio-video recorded events from the point in the script at which surgeons were asked to describe landmarks and mark skin landmarks. Recordings continued through skin incision, dissection of subcutaneous structures, and passage of a double vessel loop to gain proximal control. As previously described, simultaneous audio-video recording of these events was also captured by the ceiling mounted devices, for use in case of inadequate head camera audio and image capture. To blind the video, head-camera images showing only the operators hands and the surgical field were used preferentially. In one surgeon, only the ceiling-mounted camera image was available and this was used.

8.4.1: Video Preparation:

To prepare video material for the remote video reviewers use, performance of the cohort of surgeons was separated by tertiles of pre-ASSET training IPS Score for each of the three procedures (see Fig 8.1).

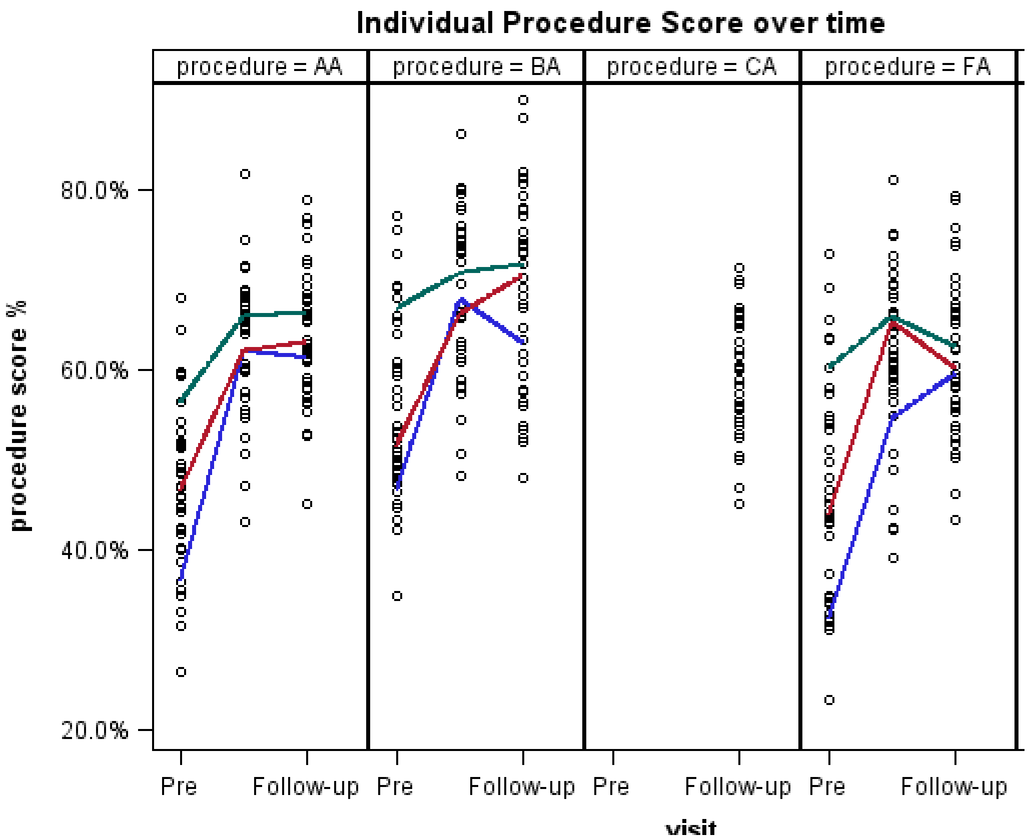


Figure 8.1: *IPS scores by co-located evaluators are on the Y axis and evaluation visit time is shown on the X axis, All 40 surgeons' performance data are individually plotted pre and post training follow-up after taking the ASSET course. Overlaid in blue red and green plots are the lower, middle and highest tertiles of pre- training IPS scores. For the purposes of preparation of video clips for blind video review, one surgeon was randomly selected from each tertile for each for each procedure.*

Using random choice, a single surgeon was selected from each tertile of pre-training IPS for each procedure. In all, nine different surgeons were randomly selected, without substitution, so that each procedure they performed was included before and after training.

In all 54 different video clips (27 before training and 27 after training) for each of the nine selected surgeons were randomly sequenced both by procedure and by before and after ASSET training for each surgeon. A storage media device containing the same sequence of video clips was given to five trained video-reviewers; three surgeons, one trauma clinician (myself), and one PhD anatomists all of whom had participated as co-located evaluators for multiple surgeons. Each reviewer independently completed their evaluations through a web-based evaluation system.

8.4.2: Blind Review of Surgical Procedure Video:

Five video reviewers evaluated video of the same surgeons performing the same procedure before and after training to minimize evaluator bias as a factor. The video evaluators were blinded to the status of surgeon training and the video clips of the procedures were in a random sequence. Three surgeons were selected randomly from the group of 40 from each tertile of Pre-Training Individual Procedure Score, so one surgeon was randomly selected from the top 1/3rd of performing surgeons before they were trained , one from the middle 1/3rd etc. . The logic for this was that the surgeons who were good before they were even trained would have less chance to improve performance than those who were in the bottom 1/3rd ...i.e. did the "top notch" surgeons remain the "top notch" surgeons? The analysis of surgeons were made for all three vascular procedures (AA, BA and FA) without evaluator bias and compared to the same procedures carried out by the same surgeons when evaluated by co-located evaluators who knew the surgeons training status. Each procedure had a different group of three surgeons selected randomly as described above, with no overlap (i.e. no surgeon included in the video review cohort was evaluated performing more than one procedure).

Each of the enrolled surgeons was evaluated as previously described, using a custom software application (App) running on a mobile Android tablet. For the purposes of the blind video analysis the script was abbreviated to include only events after the surgeon was told the patient was in the Operating Room (OR). In addition only 3 Global Ratings (Anatomic, Technical Skill and Readiness to independently perform the procedure) and one overall evaluation were assessed.

The blind video-only evaluations were completed using a desktop version of the software and used both checklists and global rating scales and captured technical performance including critical technical errors and error recovery. Medical Education Research Study Quality Instrument (MERSQI) was used to assess the methodological quality (1) by determining the study design score compared to MERSQI. The maximum weighting score of MERSQI was18, The Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) was used to evaluate study biases (2). The criteria for MERSQI and QUADAS-2 are listed in Table 8.1.

Table 8.2: The criteria for MERSQI and QUADAS-2 are shown in the Table.
Medical Education Research Study Quality Instrument (MERSQI) used to assess the methodological quality (1) by determining the study design score compared to MERSQI maximum weighting score of 18, and the Quality Assessment of Diagnostic Accuracy Studies (QUADAS-2) to evaluate study biases (2).

Evaluation of Quantitative Data and Risk of Bias

MERSQI (maximum weighting)

- Study Design (3)
- Sampling # institutions (1.5)
- Sampling follow-up(1.5)
- Types of data outcome(3)
- Validity evidence (3)
- Data analysis appropriate(1)
- Data Analysis advances (3)
- Highest outcome type (3)

QUADAS-2: Low risk/concern bias applicability

- Participant selection
- Index test: conduct or interpretation
- Index test: match with target condition
- Reference test: conduct or interpretation
- Reference test: match with target condition
- Flow of participants

8.5: Statistical Analyses:

Co-located and blind video performance evaluations were compared with a linear mixed model to account for cadaver body habitus, year of residency and gender of enrolled surgeons. Evaluator reliability was determined by inter-rater reliability using intra-class correlation coefficients (ICC). ICC ratings (0.7 good, ICC > 0.8 excellent, ICC > 0.9 outstanding) were used to assess the consistency among measurements. The reliability of the co-located and video evaluators before and after training was determined by comparing remote (blinded video review) ICC and co-located ICC for the same surgeons

8.6: Results of Blind Video Review versus Co-Located Evaluation:

Study design as judged by original MERSQI criteria (Table 8.2) scored 15.5/18, including sampling of multiple institutions, with an identified study cohort follow-up of >75% and specified post-training subjective and objective data outcome showing validity evidence from several variables including IPS, errors, timing and GRS. Data analyses were beyond descriptive analyses and the highest outcome type was knowledge, skills and behaviours. Biases examined using QUADAS-2 showed a low risk of bias in participant selection, which was random both by institution and by surgeon within that training program, and by conduct and interpretation of the testing which used a standardized script and evaluation criteria and matched the target haemorrhage control procedures closely.

When the 33 items on the technical skills checklists (see example in Appendix II) were compared between co-located and blind video review for all 3 procedures, there were no differences with a single exception, the economy of movement metric for BA was different ($p< 0.03$) between blind and co-located reviewers. Blind video review of surgeon's performance before and after ASSET training for each of the three procedures is shown in Figure 8.2. Procedure scores showed significant increase with ASSET training, with the exception of BA ($p= 0.3$) (Table 8.3). There were no differences ($p =.05$ or greater) in evaluator ratings whether the evaluators were co-located or reviewed video–recordings (Table 8.4). Evaluator consistency was good (0.3-0.8) (Table 8.4).

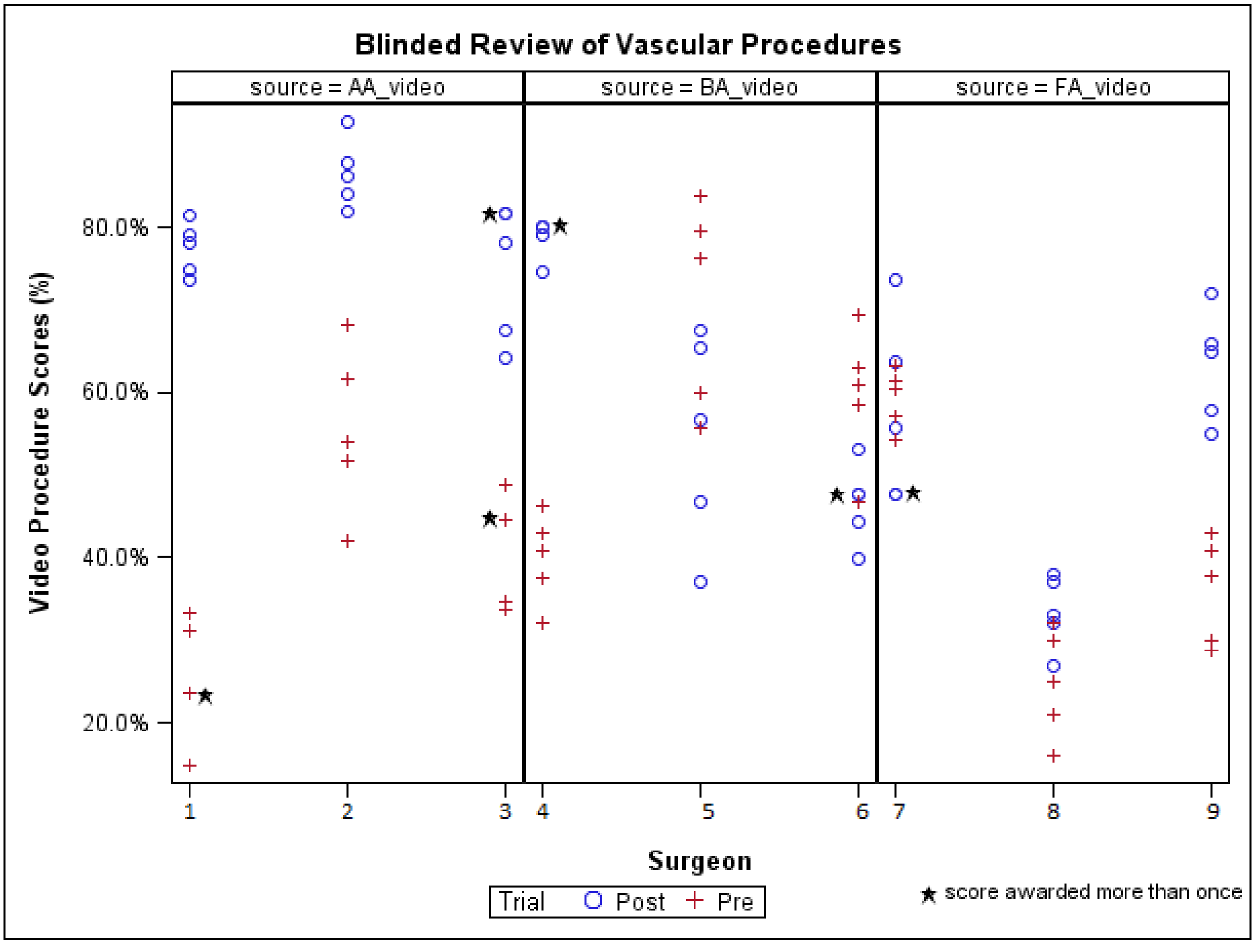


Figure 8.2: *Blind Video Review Individual Procedure Scores on Y axis are plotted against surgeon (#1-9) on the X axis. Each surgeon 1-9 had their video randomly selected as representatives on each tertile of IPS performance evaluated before ASSET training. The red cross symbols represent the Pre training blind video IPS and the blue circle symbols represent the Post- training blind video IPS of the same surgeons. No single surgeon was evaluated for more than one procedure. Each procedure among AA BA and FA had a different group of 3 surgeons. Star symbols represent an identical score by more than one blind video reviewer.*

Correlations of co-located to remote video reviewer performance assessments showed high to acceptable R values for Pearson' correlation. The blind video reviewers could discriminate significantly ($p < 0.002$) between video clips of performance of the same surgeon (video reviewers were blinded to both surgeon identifiers and pre-post trial status) in the AA and FA procedure, but not in BA, the shortest and most difficult to visualize of the three exposure and vascular control procedures. Evaluators were consistent with consistency of 0.3 – 0.6 depending on the evaluated procedure. ICC coefficients were outstanding (>0.9) for AA and excellent for FA (>0.8), good (>0.7) for BA .These results are summarized in Table 8.4.

Table 8.4: Comparison of co-located versus video reviewer p-values, ability to discriminate pre- from post- ASSET trial of training performance, and evaluator consistency for video review

Surgical Procedure	**Axillary Artery**	**Brachial Artery**	**Femoral Artery**
Type Correlation co-located vs. remote (video review) R values	0.5	0.8	0.9
Trial Pre-ASSET vs. Post-ASSET	<0.0001	0.3	<0.002
Evaluator Consistency	0.48	0.3	0.6
ICC Coefficients	0.92	0.73	0.84

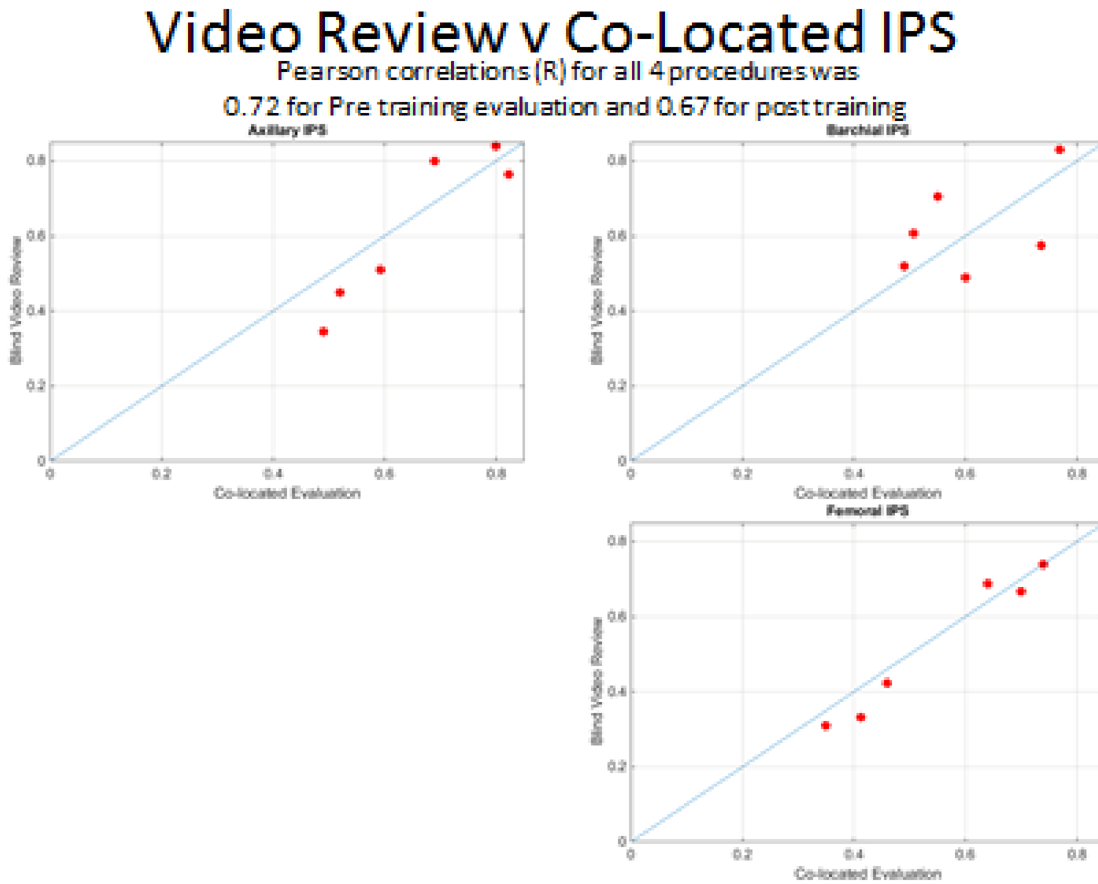


Figure 8.3: *Correlations of 5 video reviewers evaluating 12 surgeons performing 3 procedures. Y axis video Individual Procedure Score (IPS), X axis mean of two Co-Located IPS scores of same surgeons performing the same procedures. From Top Left Clockwise: Axillary Artery (AA), Brachial Artery (BA), and Femoral Artery (FA). IPS for Video review and co-located Pearson correlations (R) for all 3 procedures considered together for the same surgeon was 0.86 for Pre training evaluation and 0.79 for post training.*

8.8: Global Rating Scale Scores:

When the four global ratings (Anatomy, Technical, Readiness and Overall evaluation) were compared between co-located evaluators and blind video reviewers, Readiness to perform the procedure had the greatest agreement for BA p=1.0 next AA p=0.7 and least FA p =0.06. For Anatomy Knowledge, p = 1.0 for BA and FA, p= 0.7 for AA. For Global Technical Skills ratings, p values were 0.2 (FA) to 0.7 (BA). For Overall evaluation, p-values were, 0.2 (BA), and 0.1 (AA). There was one significant difference between co-located evaluators and blind video reviewers in overall global evaluation rating for FA (p< 0.03).

8.9: Blind Video Rater Reliability/Consistency:

ICC reported above, shows that the co-located reviewers had a high consistency of inter-rater agreement in excess of 0.8 (and by this measure they were reliable). In 54 of the randomly ordered videos, all 5 of the evaluators unknowingly reviewed the same video more than once allowing a reliability measure to be made. The reliability shows no differences in repeated reviews of the same videos (Table 8.4). In addition to reliability, there was consistency in evaluation inherent in the use of the standardized testing produced as a result of the script-driven assessments. All surgeons had an identical testing scenario. Differences in cadaver body habitus were noted for each procedure (obese, normal, thin), accounting even for localized obesity such as can occur with differences in upper and lower extremity anatomy. Anatomic anomalies (aberrant vasculature, the most frequent of which was in the FA procedure when the profunda femoral artery had variable locations in relation to the inguinal ligament) were also noted during the evaluations and accounted for in analysis the body habitus features and anatomic anomalies were included in the mixed model for analysis.

8.10: Chapter 8 Discussion:

The design and lack of bias in this study determined by MERSQI and QUADAS-2 criteria strengthens the evidence showing that there were no major differences between co-located and video evaluations of three trauma-related open vascular exposure surgical procedures. By using blind randomly arranged (pre- and post-ASSET training) review of video, in which only a pair of surgeons hands were visible, evaluator bias was minimized for evaluation of the three procedures. The agreement between co-located and blind video reviewer evaluations of technical skills is remarkable. One of the 4 procedure checklist evaluations showed significant difference and then for only 1/33 items for BA procedure. Importantly, recognition of critical technical errors was identical for all the vascular procedures the remarkable agreement is a reflection of the reviewer and evaluator training and consistency and the robustness of the metric that was rigorously defined. The error recovery metric was equally robust and equally consistent and in agreement between co-located evaluators and blind video reviewers for all the vascular procedures. These findings on checklist agreement and error recognition and recovery are highly relevant as they provide strong evidence to support evaluations using audio-video recording. This could either be in real-time at a central, but remote location, or asynchronous at the convenience of the video-reviewer. Such remote and asynchronous evaluation using video would greatly simplify conduct and coordination of formative evaluations. This would be especially true for use of video recording for evaluations of real surgery in the operating room. The findings of this study using IPS metrics for these procedures suggest that co-located evaluators may not be needed for assessments as there is no loss of quantitative data.

8.10.1: Evaluator Agreement and Consistency:

Within evaluator agreements were good to outstanding, with the exception of the agreements for BA procedure. There is a possible explanation for why BA is the exception. BA landmarks are particularly vague and non-bony (groove between biceps and triceps). In addition, the video recordings of surgery performed on the medial side of the humerus did not obtain the overhead viewing angle, as was obtained for FA and AA procedures. For BA procedures there were sometimes pedunculated fat pads under the humerus and loose skin, making evaluations and video recording of adequate views difficult when the cadaveric arm could not be fully externally rotated.

8.10.2: Previous Reports of Blind Video Review:

Video recordings have been used for debriefing feedback after simulation or real surgical cases and also for self-assessment (186). The European Board of Vascular Surgery uses simulated sapheno-femoral disconnection (SFD) as part of the examination (139, 187). To determine whether this would be valid for summative assessments, ICC between direct observation by a single co-located surgeon and blinded video tape assessment of SFD performed by 33 surgeons varied from 0.83-0.92 (138, 139). When blinded video of a competent consultant surgeon performance and an inexperienced trainee performance of SFD were evaluated by 14 consultants and 14 trainees using an 18 point checklist containing global items, there was complete separation of the scores for the experienced and inexperienced surgeons (138). The reason suggested for the high reliability and ICC was that SFD procedure has little anatomic variation or difficulty. This Thesis study showed similar ICC for AA, and FA even though these procedures have considerable anatomic variability and difficulty for many surgeons.

8.11: Study Limitations:

The IPS has not been validated as a metric that would be transferrable to the real clinical environment. The IPS metric was developed with the surgeon operating solo without other members of the operating room team. While this is not the clinical state of the surgical domain, the testing format allowed the unassisted surgeon's capability to be individually assessed without confounders of advice or prompts. Such prompts might be expected in the real operating room should surgeon performance deviate from standard operating procedure. The cadaver is generally accepted as the real patient representation with the greatest fidelity, but many of the co-morbid states found in trauma patients such as bleeding, tissue injury and swelling were not present in the cadaver.

8.12: Study Strengths:

Enrolled surgeons were enthusiastic participants, only one was lost to follow-up and easily replaced by an additional enrollee. The evaluators were well-trained and experienced anatomists, surgeons and trauma clinicians who had previously functioned both as co-located and video reviewers. The lack of bias, consistency of the scripted evaluations, and electronic capture of real-time co-located evaluations are important considerations that strengthen the findings. The concurrent validity of IPS, timing, errors, and global ratings that can discriminate performance pre- versus post-ASSET training further validates the conclusion from the earlier study (188, 189) in these same surgeons that the IPS metric is a benchmark for the AA, BA, and FA procedures.

Blind video review of randomly sequenced video recordings of identifying the procedure specific landmarks marking the skin, incisions, and proceeding to vascular exposure of AA, BA, FA showed that the IPS metric can discriminate pre- versus post-ASSET training whether the evaluation is made by co-located or video-recorded evaluation. Error recognition and recognition of error recovery were identical between co-located evaluators and those reviewing video recordings. Such un-biased evaluations have considerable potential for formative assessments of competency and may also be useful for determining readiness of military surgeons for deployment.

8:13: Summary Conclusion Chapter 8:

Chapter 8 demonstrated that the IPS technical skills metric is robust and can be applied when viewing surgeon performance of open surgical procedures for trauma. The studies provide convergent validity of findings with co-located evaluators. Refreshing skills for previously ASSET trained surgeons should include focus on review of anatomy, landmarks and procedure specific steps. Benchmarking expert performance by IPS is a standard for comparison of surgical skills after training and readiness before deployment. Evaluation of performance by video review rather than requiring co-located evaluators would simplify the logistics of trauma core competency evaluations as assessing surgeon readiness for deployment could be determined asynchronously by remote video evaluators. The findings that video and co-located evaluations are similar and critical error recognition identical, suggests that Surgical Telementoring and Telemedicine may be beneficial as video evaluations of trauma core procedural competencies were un-biased, valid and consistent. Head-Camera Video evaluations of surgeon performance have potential for formative assessments of competency by Teleproctoring.

These results, together with the entire Thesis, are reviewed and discussed in the final Chapter 9.

CHAPTER 9: General Discussion of Thesis Findings, Implications, Future Directions, Innovations, Military Readiness and Personal Reflections.

9.0: Overview of Chapter 9:

This Final Chapter of my Thesis ties together the findings of the previous Chapters. The findings are put in context of the potential impact of being able to measure surgeon performance for emergency open trauma surgical procedures. Emergency surgery is quite different from surgery for elective interventions. Planning and preparatory team-work available for elective surgery is often lacking in emergencies where *ad hoc* teams and contingencies not normally engaged are called upon to provide care, where resources are stretched and experts maybe unavailable. Solo unsupervised surgeons may be "the best there is" to do the emergency case, especially when multiple emergencies need simultaneous surgical care. Chapter 9 identifies the key findings and novelty of the Thesis effort and summarizes the implications of the findings and future directions. The tangible innovations are enumerated and the military relevance of the results is described. A brief Personal Reflections section describes what I learnt as a result of conducting the work included in this Thesis

9.1: Thesis Findings:

9.1: Was my Thesis Hypothesis Supported by the Results of Testing?

The hypothesis tested by the studies reported in my Thesis was: - surgical performance measures can be developed, and validated to demonstrate the effectiveness of ASSET training in emergency vascular control procedures for extremity injuries. The hypothesis was addressed as three inter-related questions:

a) Do trauma surgical skills show improvement with training?
b) Which components among these skills benefit most from training?
c) Does training reduce the occurrence of error?

As a result of the efforts reported in the preceding chapters a trauma-specific surgical technical and non-technical skills performance assessment tool was validated with good to excellent inter-rater reliability for three vascular exposure and control procedures. ASSET training reduced time to vascular control by 2 ½ minutes. The validated tool detected improvements in landmarks, anatomic knowledge, completion of specific procedure steps, and surgical technical skills after training with a 1-day course. The data also show a reduction in errors in correct recognition of the extremity vessel by approximately 50 % or more, and an improved error recovery rate for most vascular exposures. The error recovery improvement was demonstrated by self-correction of the errors in extremity vessel identification.

9.2: Key Findings from Each Chapter of Thesis:

Chapter 1 outlined a succinct capability gap of vascular exposure, haemorrhage control and trauma core competencies for civilian and military surgical training programs. This gap has occurred because there is limited training and clinical practice for current surgical trainees in these technical skills for proximal vascular exposure and control. Chapter 1 identified a need to develop performance metrics for open vascular exposure and vascular control, then justified and identified my approach to rectifying this deficiency.

Chapter 2 described a literature review of trauma surgical training courses and concluded that the evidence supporting their benefit only reached Level 2-3 or in one case possibly Level 4, leaving the training benefit of the remainder of these courses un-validated. This lack of validation of benefit is surprising since the majority of trauma surgical training courses involved use of cadavers or live tissue and courses were expensive and time-consuming. Chapter 2 also suggested that alternative ways to acquire and maintain surgical technical skills for trauma should be explored, including: “heads-up displays”, use of deliberate practice, and mental rehearsal tools, mobile training platforms and tele-mentoring, as trainees today have half the open surgical operative experience of 10 years ago.

Chapter 3, a literature search of the multiple systematic reviews of surgeon performance metrics that were published in the last six years, showed that there were no metrics for measuring technical and non-technical skills for core trauma procedure competencies. The conclusion was that such a performance benchmark is a prerequisite to establishing if additional training is of benefit and determining if military surgeons are ready for deployment. The need for a performance benchmark metric for trauma procedural skills influences all the remaining six Chapters of my Thesis.

Chapter 4 describes the general methods common to Chapter 5 onwards, to achieve such a performance benchmark, the study design, analysis, sample size justification necessary for validation, the data dictionary and standardized script that were essential to the strength of findings for the Thesis effort.

Chapter 5 compares surgeon self-evaluated performance with Global Ratings of Performance to identify the gap between surgical resident's perception of their own performance and evaluations by trained evaluators who were co-located with these surgeons while they answered questions and performed the procedures. Chapter 5 showed how divergent self-reported resident performance was from Global Ratings used by trained evaluators. Residents were unable to recognize their own lack of surgical skill for core trauma competency in vascular exposure procedures for AA BA and FA.

Chapter 6 reports preliminary analyses for the extremity vascular exposure metrics included in the Individual Procedure Score; pilot testing of the Standardized Script; Inter-Rater Reliability of evaluators and initial findings of expert versus un-trained surgeons. Chapter 6 showed that testing by blind video review discriminated randomly arranged de-identified video-recordings of experts from untrained surgical residents using these newly developed metrics.

Chapter 7 tests 40 surgical residents from 13 different surgery training programs in the North-East US before and after training in technical and non-technical skills achieved by taking the one-day cadaver-based ASSET course. Chapter 7 demonstrated by IPS component testing before and after training that the ASSET course significantly improved performance. Identification of those surgeons who do not show improved performance with training is necessary. IPS is a metric to identify these surgeons when they score below the 6^{th} decile in IPS. These surgeons require remedial interventions to rectify their technical skills deficiencies with the major interventions being to teach correct procedure surface landmarks, to ensure the incision is correctly placed, and to enumerate the procedural steps and anatomic relationships of nearby structures. The conclusion about the need for overall anatomy training was made based on the correlation of correct surface anatomic landmarks and incision placement with correct identification of the artery in a shorter time than those surgeons who failed to identify landmarks correctly. This finding seems intuitively obvious in theory, but has not been recognized in practice by the surgeons themselves.

Chapter 8 assesses the impact of bias and describes convergent validity of surgeon performance metrics data when evaluators were blinded by use of video review from head-camera images of surgeon's hands performing the core trauma competency procedures. Chapter 8 completed the definitive test of the IPS metric by finding that even with video blinded to whether or not the surgical residents were performing the procedures before or after they had taken the ASSET course, year of residency and other resident surgeon demographics, trained video evaluators and co-located evaluators scores for technical skills and errors were no different. This lack of bias in the evaluations supports the robustness of the IPS metric.

That IPS can detect the benefits of ASSET training, and the agreement among the IPS scoring, GRS, error occurrence and recovery, between blind video analysis and co-located evaluators demonstrates the convergent validity of the IPS metric. By further extension this reasoning also applies to the overall trauma readiness TRI metric, as it is the sum of the independently evaluated IPS of the AA, BA and FA procedures. The implications of this finding are important, as it infers that video-recordings could be used for determination of military pre-deployment trauma readiness, competency assessments, tele-mentoring and future evaluation of competence by tele-proctoring.

In what follows, I review the major findings of the Thesis, the implications, innovations, future direction and potential impact on military readiness. Finally, my Personal Reflections summarize what I learnt as a result of completing the Thesis.

9.3: What Generic Performance Issues Were Detected and How Can They Be Rectified?

9.3.1: Baseline Knowledge of Anatomy:

An important general finding of this study was the low baseline knowledge of human anatomy found among surgeons during the performance of the three vascular exposure skills when tested before training. Expert evaluators found that residents would be unable to perform these procedures without significant help 65%–86% of the time (variability based on the procedure). Additionally, regarding independent practice, as few as 10% of residents were thought capable of immediately performing extremity vascular exposure procedures without assistance. Given the current limited training in the skills tested and decreased operative autonomy by residents, these numbers are not completely unexpected and should serve as a call to critically evaluate the current training paradigm. Although it is difficult to directly equate actual case numbers with performance, it is known that surgeons performing more procedures have better outcomes (181), so it is also reasonable to equate the judgment of being unable to perform exposure unassisted to substandard performance. This finding serves to reinforce the previously described concerns over the declining surgical experience (51, 163, 190-197). A number of other studies bolster these concerns that graduating residents have a gap between expectations and experiences and that there is also a significant lack of confidence in performing a variety of open surgical procedures (198-202). Although surgical residents did rate their confidence higher than ultimately scored by the evaluators, the IPS scores of residents showed large variability and the IPS for the three procedures were still low. When addressing concerns about gaps in training, Bell et al. (198) concluded that “methods will have to be developed to allow surgeons to reach a basic level of competence in procedures which they are likely to experience only rarely during residency.” This conclusion was echoed by Malangoni et al. (199) who suggested that “education in the operating room must improve and alternative methods for teaching infrequently performed procedures are needed." Short, focused cadaver-based training courses, for procedures that are rarely performed, is the approach currently being advocated in the US surgical training programs. The ASSET course described in this Thesis is such a course. Validation of ASSET training efficacy is an important step to a broader recognition and implementation of this training. This validated IPS tool could be used to demonstrate competency in comparison to expert performance for surgical skills courses, general surgery residency, trauma fellowship, or military pre-deployment training. IPS could be used to measure performance of surgeons in simulated and real workspaces and contribute to the range of testing modalities available to educators, training course designers, and surgical quality assurance programs.

9.3.2: Facilitation of Extremity Vascular Exposure:

Each of the three procedures requires identification of key anatomic structures to facilitate successful recognition of the artery, when no arterial pulses are present. For axillary artery it is identification of the pectoralis minor muscle, incision of pectoralis minor 2 cm inferior to the humeral insertion reveals the underlying axillary artery. For brachial artery the incision should be made in the groove between biceps and triceps muscles and the neurovascular bundle should at all times be related to the underlying humerus to ensure that the incision is in the correct tissue plane. For femoral artery the incision is placed vertically through a line 1/3rd the distance (or two finger-breadths lateral) to the pubic tubercle and anterior superior iliac spine, the vertical incision extending 2-3 cm above the inguinal ligament. The common errors performing brachial artery exposure were mistaking the median nerve for the brachial artery. For femoral artery exposure, the common error was incision placement too low so that the superficial femoral was mis-identified as the common femoral and a branch other than the profunda was therefore incorrectly selected. For axillary artery injury (on the cadaver shoulder), the commonest error was incision placement in the axilla (with failure to obtain proximal vascular control) rather than making the incision inferior to the clavicle.

Table 9.1: Key Findings of Thesis summarised:

1) The IPS metric demonstrates increased technical and non-technical skills for AA, BA, and FA with training in the ASSET Course.
2) The components of IPS: Anatomy (including landmarks, skin incision) and specific procedural steps were the key skills gained.
3) Critical Errors were significantly decreased with ASSET Training; and error recovery significantly increased.
4) Global Ratings were not correlated with errors.
5) IPS Performance showed almost 100% variability after training, and identified 5 surgeons showing no benefit from training
6) There was a cohort of surgeons who had repeated and consistent errors despite training.
7) Over half the surgeons increased their overall vascular exposure performance (judged by TRI), indicating usefulness of IPS (or the sum = TRI) in formative assessments.
8) IPS can discriminate pre- versus post-ASSET training including error recognition, whether the evaluation is made by co-located or video-recorded evaluation
9) IPS evaluation had good to excellent inter-rater reliability, rater consistency and reliability

9.4: The Challenges of Studying Complex Trauma Skills—Validity Boundaries:

I have discussed limitations of the research studies I undertook as part of my Thesis in some detail in the preceding chapters. Here, I present what I consider a key, major challenge to studying skills required for complex trauma surgery in a simulated environment, which sets the boundaries within which the findings of my Thesis are externally generalizable and transferable to surgical management of trauma *in vivo*, particularly in the military setting. Trauma surgery is a very complex and increasingly team-based set of tasks requiring coordination of multiple different tasks and rapidly integrated motor, cognitive, social, and emotional skills. Acquisition of skill in such complex task variants may not follow a smooth power law function trajectory as has been described for basic performance research. Such research performed on simple task training suggests that acquisition and degradation of skills follow a power law function: http://ritter.ist.psu.edu/papers/kimKR07.pdf (10) whereby performance improves substantially during the early phases of learning but plateaus with little payoff with over-practice in later stages of mastery. With simple tasks, everything that is to be learned is learnt rapidly with no further payoff. Similarly, skill decay is rapid in the absence of experience immediately after acquisition but occurs much more slowly later. These findings suggest that any substantially delayed intervention (more than days), on simple tasks at least, happens on the flat portion of either curve, making the precise timing of delayed training intervention for such tasks largely irrelevant. Unfortunately, extrapolation from simple to complex tasks may not be valid. Basic performance research tasks tend to be simple, suitable for use in a laboratory setting with undergraduate students as the most commonly recruited subjects.

In the complex task of trauma surgery, the process of acquisition of a new skill maybe quite different from that occurring with simple tasks and undergraduate trainees. For complex tasks, such as emergency trauma care, insight acquired during key encounters or training may reorganize knowledge or add new constraints that result in step-wise changes in capability (87). We do not know how well such research findings generalize to complex skills like surgical performance. In particular, the conceptualization of procedural skill as repetitive and decontextualized is suspect when considering surgical procedures such as those studied.

9.5: Key Methodological Innovations:

9.5.1: Mobile Tablet Data Collection in Real-Time:

It would be difficult to over-estimate the value of the real-time data collection using the Mobile Tablet. The tablet software was all that was required to provide the instructions to the enrolled surgeon about what the study process would be in a standardized manner. The software provided touch-screen data entry for checklists, or 1-5 scoring for Likert scale entry with each score having a description of its meaning, and a 'touch screen and drag' sliding scale of 1-100 for overall ratings. The tablet software forced the evaluator (by preventing passage to the next item) to complete all the data collection fields. The software logic controlled linked questions (e.g. prevented checking BOTH correct identification (ID) of an artery AND error in vessel ID). The software also prevented progress to the next in a series of procedures, until every evaluation response was completed, ensuring 100% data collection for each procedure evaluation. Another advantage of the Tablet Application was that the slides used in the Case-Based scenario were embedded in the Tablet displays in the same sequence as the surgeons were shown the case details and slides on the larger wall-mounted display. In fact, the Tablet alone would probably have sufficed to explain the simulated case, with the exception that some of the fine-grained information in X-Rays would not have been detectable on the small Tablet Screen.

9.5.2: Standardized Script:

A core component of comparisons between pre- post- training and follow-up among residents, practising surgeons and experts was the standardized script. Each of the surgeons was given the same instructions, asked to do exactly the same things and respond to exactly the same worded questions every time the surgeon evaluations were made. However, there were separate standardized scripts for each procedure, designed with same format and software scoring system. A screen by screen summary of the software options is shown in the Appendix. III. My surgeon and anatomy collaborators, designed the Tablet screens iteratively with the programmers at Swinburne University, Melbourne Australia over a 6 week period after the finalized version of the script had been agreed at the consensus conference described earlier. The order of entry into a given upper or lower extremity script was selected according to how many other surgeons were being concurrently individually evaluated on adjacent cadavers. The intent of this flexibility was to avoid a nearby surgeon hearing another surgeon response to a given question. This was an especial concern if two surgeons would be operating side-by –side on separate cadavers but on the same surgical procedure.

9.5.3: Summary De-briefing Evaluation:

On completion of each procedural evaluation, the scores and evaluation summary comments were calculated. The tablet screen display could either be used as a debrief tool to provide the surgeon with an absolute score in each procedural step, or more generally as a means for the evaluator to have a quick overview performance summary of the strengths and weakness of the performance of that particular surgeon. Now that over 100 surgeons of three different levels of expertise have been enrolled and their performance data has been analysed, it would be possible to provide instantaneous ranking of an individual surgeon by peer group (e.g. other residents), or in comparison to a cohort of experienced Attending/Consultant Traumatologists, or in comparison to Consultant general surgeons in routine clinical practice. Rapid debriefing sessions are known to support learning, especially when reviewing rarely performed procedures in solo performance situations. Verbal expert evaluator de-briefing in close proximity to the event is known to be especially powerful (203-205).

9.5.4: Head Camera with Laser Pointer:

The head camera is an inexpensive (US$ 100) innovation. Several years previously I had used an early version of a head camera worn by the leader of the Shock Trauma Resuscitation team while working in the real clinical domain. In addition, I had used a very expensive (US$ 30,000), eye-tracking device to detect responses to alarms and to compare surgeon, nursing and anaesthesiologists eye-tracking when viewing exactly the same video recordings of trauma patient resuscitation. The simple head camera not only stored and recorded video, but the audio quality was excellent, sufficient enough to allow transcription of these recordings with over 99% accuracy. The laser pointer functioned in a similar fashion to the eye-tracking device to detect the surgeons gaze pattern. It was not as accurate (+/- 2 cm) as the expensive device because the camera did not always remain in constant position throughout a procedure and it was off-set to one side of the surgeons head, so when in close proximity to the cadaver, the direction and the laser pointer was not accurate.

9.5.5: Cloud Server for Upload:

The data entered into the Tablet was uploaded at a moment of approval of the question Data Ready for Upload? The Tablet was required to be synchronized with a network for the upload to occur. This was initially problematic as the Anatomy Board Laboratories were in a Sub-Basement without adequate wireless coverage. We added WiFi hotspots and overcame this problem. However, we have subsequently revised the software to allow storage of the evaluation and adjustment of data entry on the Tablet after the debrief. This was necessary because cadaver-based debriefing occurred by the Senior Evaluator after the surgeons had completed all the procedures. During the debrief, the surgeon's performance on each procedure was described. The surgeon was often asked to complete further dissection if the evaluator or the surgeon doubted this assessment. As a result sometimes the evaluation required changing. When data required uploading before proceeding to the next procedure, the evaluation could not be changed. Instead we had to make a note and change the entry when the data was downloaded for analysis. Storage of data on the Tablet before uploading to the cloud has rectified this problem, as changes can still be made before data upload.

9.5.6: Data Download in Excel Format:

Once uploaded the files could be downloaded in batches. The download was programmed so that these data were formatted into Excel spreadsheets for further analysis. This became problematic for one batch of downloaded data. The data could not be unscrambled and some was forever lost. This was the final stimulus for us to reprogram the Tablet App to allow storage of evaluations on the Tablet itself and completely avoid using the Cloud storage. The tablet data was then downloaded to our memory bank computers for storage.

9.6: Implications and Future Directions:

9.6.1: Validation of Surgical Skills Training Courses to Demonstrate Benefit:

To increase the likelihood that surgical skills training occurs in a educationally robust setting with metrics and validation that conforms to accepted standards such as Kirkpatrick's (130) and Messick's (132), a straightforward approach would be to focus on evaluating existing courses, rather than developing more of them. Even for the better evidenced courses, e.g. ATLS, the evidence base lacks robust control groups. Lack of controls and over-reliance on before/after study design is a major problem in the clinical education literature. An outcome of this Thesis is the realization that the majority of surgical skills courses involved a large expense, use non-clinical time and have undocumented benefits. Course registries should be established. Training outcomes should be systematically reviewed, and tested to identify the training approaches and tools that work to generate the improvements in the skills and it is to be hoped, the subsequent transference to improved clinical performance and patient outcomes. Course proliferation is sometimes driven by financial incentive and this is a problem when there are numerous courses of variable quality competing with each other, with no clear guidance available. As can be seen from Chapter 2, Table 2.1, some of the surgical skills training courses with the greatest cost have no published data on course efficacy. Consolidation among existing course to concentrate on their training strengths and validation of metrics is suggested.

9.6.2: Future Implication of Competency in Vascular Exposure Procedures:

The implications of a robust vascular exposure performance metric are that specific skills acquired during the course of surgeon residency training could be evaluated, military surgical readiness, and skill degradation with time since training could be quantified. Real-world operating room studies are needed, but would be confounded by the effects of team performance versus individual surgeon performance on patient outcome and the need to exclude the influence of non-technical factors on surgeon technical skill (206). Future research on training surgical skills should include research designs with technical and non-technical performance metrics (43). The implications of surgeon performance measurements are multiple. They include enhanced individualized post-procedural debriefing, personalized skills refreshing, serial evaluation throughout training, formative and summative assessments of competence to perform surgery, even specific surgical procedure competence. Surgeon performance measurement would also assist identification of surgeon skill degradation and for military surgeons, “readiness for deployment”. The effort and cost of skills maintenance is significant and both could be reduced by focus on a surgeon’s measured performance deficits and by use of directed training and technology support to assist personal skill remediation.

Table 9.2: Future Trauma Procedural Studies That Should Be Completed:

1) Demonstrate that completion of a Trauma Training Course improves performance in emergency haemorrhage control in real trauma patients.
2) Standardize measures to assess individual surgeon performance during emergency open vascular and haemorrhage control procedures.
3) Design studies, by consensus among participating trauma centres, to evaluate transfer of technical skills, (and the design should also include knowledge, clinical judgment and other non-technical skills) from non-live tissue and simulator training to real-life clinical performance.
4) Conduct studies and collect evidence of retention of technical and non-technical trauma surgical skills to support the time-interval of degradation and the need to refresh these skills when interval trauma experience is lacking..
5) Cost/Benefit analyses of the multiple trauma surgery training courses should be conducted to optimize benefits and produce the best outcome in the shortest interval at the least cost using multiple approaches helpful in these courses.
6) Determine from sufficiently powered studies if generalizable components of haemorrhage control procedures trained in simulators to asymptotic performance improve clinical performance during emergency haemorrhage control in real trauma patients.
7) Include use of only the most cost/benefit effective among cadaver, virtual reality and physical full-mission simulation and part task-trainers for testing of competence.

A further implication of the Thesis findings is a need for exploration of why there was large variance in performance scores found among surgeons after ASSET training. The IPS surgical performance evaluation criteria are good at capturing technical skill, but may not necessarily capture certain cognitive aspects of skilled performance such as how surgeons identify problems and plan actions and execute them. Variations in the evaluators could influence performance scores and need to be accounted for, because variance in scores may occur from some factor in the performance scores not captured by the checklists and GRS used in evaluations of surgical skill. A global rating is a cognitive task that involves the evaluator recognizing multiple aspects of cues in surgeon performance and decision-making and incorporating multiple criteria based on rater-specific weights and preferences. Global ratings may be affected by biases, where a general impression or subset of performance affects other ratings. It was my belief that global ratings would be impacted by whether an evaluator noted that a surgeon made a technical error. A secondary version of this hypothesis was that a surgeon who scored highly on the non-technical knowledge and patient management would be rated higher on global technical skill and overall global evaluator rating. Both of my thoughts on this proved to be wrong, as global ratings did not capture the occurrence of critical technical errors, and surgeons scoring well on the responses to patient knowledge and management problems did not have a strong correlation with technical skills scores. However the checklist IPS did show a strong correlation with errors, with exponential increase in errors when IPS went below the cohort 6th decile.

9.6.4: Errors and Identification of Need for Remedial Intervention:

The finding that errors were repeated by five residents despite training has implications for surgical training program selection and for progression within surgical training programs. This sub-group of five residents from among the 40 residents had repeated and consistent errors. Not only did they make more errors including critical technical errors, than the rest of the residents, but many of them made exactly the same errors after training as they did before they took the ASSET course, despite debriefing in which these residents were shown how to correct the error. The errors such as passing a vessel loop around the incorrect structure (i.e. a nerve located near the artery) and not recognizing this, in the real-world patient care situation is potentially life-threatening to the patient and career-ending for the surgeon. So these error data captured high-stakes issues in my Thesis. Failure of these surgeons to learn from their earlier mistakes and repeat the same again suggests remedial intervention is needed, as these five residents had a skills acquisition deficit. This finding alone identifies a utility for the use of the IPS metrics for surgeon training programs to help them identify surgeons who should receive individualized training intervention before progressing further in the training program.

9.6.5: Implications for "Good Hands" Theory:

A further aspect of the variability of surgeon performance is the "Good Hands" theory. Some surgeons have "good hands" and economy of movement, a manual efficiency in performing a surgical procedure. This is often accompanied by a shorter duration of surgery. Observation of two cardiac surgeons and a nurse working through an open sternum with lung inflation intermittently minimizing the field of view can be one of the most extraordinary examples of coordination in the medical profession. It may be difficult for a non-expert to understand the level of expertise and anticipatory behaviour required to achieve coordination of six pairs of hands and instruments moving in and out of the chest with continuous motion and no mixing of instruments, hands and sutures. Some of the surgeons in this study did not have "good hands". However much these surgeons were trained, I suspect they will never reach the pinnacles of excellence displayed by some surgeons I have seen operate. High performance in personal hand –eye coordination and psychomotor skills are the ultimate determinant of surgical technical skill, all other considerations being equal.

The model presented in my Thesis in which solo surgeon performance was evaluated without prompting or supervision suggests wider application to test surgeons (in such an error tolerant situation as the cadaver laboratory) performing procedures to judge whether they can operate unassisted, before being allowed into independent practice. The finding that components of the IPS showing most benefit from ASSET Training have implications for improving the ASSET course itself, by putting more emphasis on these anatomy and procedural steps aspects that surgeons in this study acquired. It makes intuitive sense that the surgeon who knows the correct surface landmarks for an artery will more likely make the skin incision in the correct location, and will therefore link mental imagery of the anatomic structures around that artery to the structures actually found, as they progress with surgical exposure. These surgeons will therefore be more successful in finding that artery in a shorter time than surgeons who place their incision incorrectly. I found ample evidence for this line of argument when evaluating the surgeons enrolled in this study, who were operating without supervision (a rare circumstance in US surgical training). If a surgeon made the initial incision incorrectly, they struggled to orientate themselves and in many circumstances in which the procedure could not be completed within the allotted 20 minutes, incorrect skin incision placement was the prime reason.

9.7: Military Relevance of Findings:

My intention with this effort was to identify a method to validate a surgical skills training course that has wide application in the US military as a Pre-deployment training vehicle. Lack of current readiness in combat surgery skills has been identified as a significant barrier to military medical readiness for surgeons. No clear standards or data exist for interval evaluation or refreshment of critical combat-specific surgical skills. The IPS metric could determine whether a surgeon is competent to be deployed and potentially IPS could determine the timing of when and whether surgical skills “refreshers” should be conducted. Competence is not merely a function of numbers or exposure to procedures, but deliberate practice of and reflection on proper performance of the procedures, guided by a relevant understanding of the underlying anatomy.

The validated IPS metric, wireless tablet software and head-camera video recording of procedures on cadavers together, make a mobile platform for surgeon competency-testing combination that could be used to evaluate competence of military surgeons before deployment. A further less expensive and more easily implemented alternative would be to use video recording demonstrations of correct and incorrect landmarks, incision placement procedural steps and anatomic relationships from my existing library of video recordings. These could be used as a “refresher”, as a means of deliberate practice, or the correct procedural video recording could be used as “heads up displays” in real-time during surgery or with addition of tele-mentoring. Such decision support and “just-in-time training” aids may be useful for both military and civilian surgeons unfamiliar with some of the rarely performed vascular exposure procedures.

The recommendations for future implementation of the Thesis findings are summarized in Table 9.3.

Table 9.3: Recommendations:

1) IPS scoring should be used during ASSET course training for AA, BA, FA to provide performance feedback and summative evaluations to determine surgeon competence.
2) Remote evaluation of audio-video recorded performance of surgeons from head-mounted and overhead cameras could be used to simplify procedure based skills evaluation.
3) Targeted skills refresher should include correct incision landmarks, procedural steps and structural anatomy for AA, BA, FA procedures.
4) The Mobile App should be fielded to centres 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

9.8: Personal Reflections:

Because I was the principal investigator and organized the meetings to write the funding request, I was able to plan the effort as I wanted to conduct these studies. To prepare the funding request, I spent 3 months meeting with collaborating surgeons to edit and finalize the text of the ultimately successful grant proposal. The preparatory groundwork allowed me to establish rapport with this group who included 3 trauma surgeons, a statistician, a Human Factors Engineer, a Faculty level Computer Scientist and a Technologist. I was also fortunate to have access to cadavers and the resources of the Maryland State Anatomy Board and to the leader and primary developer of the ASSET Course Curriculum (Col (Rtd) Mark Bowyer MD FACS).

After the award was made (one of only two in a highly competitive peer-reviewed contest), the core group of collaborators started meeting weekly (in person for some and by Teleconference for those who joined the meetings remotely). In retrospect, this was a key organizational move to coordinate all the activities of the group. I chaired these meetings scheduled at the same time each week so that they got onto everyone's schedule. A further key to the success was the early submission of Institutional Review Board (IRB) request, so that when funding was approved I already had a University of Maryland IRB approved protocol to submit to the US Army, so that their approval to start the 3 year funded study was expedited. This forward planning was vital, as we had proposed to follow-up skill retention for up to 18 months after training as part of the larger study (described very briefly in Appendix VIII).

Methodological successes were the development of a standardized script with input from subject-matter-expert consultant (Attending) Level-1 Trauma Centre surgeons. The mobile Android App was also a huge success as judged by 100% data collection of components of the IPS score when this App was used. Until we had analysed the preliminary data we used a pencil and paper data collection tool. Approximately 5-10% or responses were either not collected or were inadequately recorded. In a future the knowledge based data collection could have been simplified by having surgeons complete a multiple-choice question (MCQ) examination to test this aspect and avoid the evaluators having to ask many questions and interpret the answers if the surgeon did not give the word-perfect response. Such a MCQ exam would shorten the process of evaluation as the MCQ could be given to some surgeons while they waited to start the operative portion of technical skills evaluation.

The most surprising aspect of what I found was the huge variability in surgeon performance, not only among residents enrolled in the studies reported in this Thesis, but also among practicing surgeons and experts enrolled in the larger study funded by the US Army. A subset of this finding was that some surgeons showed no change in their performance, judged by IPS and GRS, despite taking the ASSET course training. This same subset of surgeons not only showed no performance improvement but several of these surgeons repeated the same errors before and after training. The repeated and persistent errors were made despite all surgeons receiving a comprehensive de-briefing after each evaluation that included verbal review of performance and demonstration of correct procedure, as well as an opportunity for the surgeon to continue the dissection with guidance (e.g. when they had taken more than 20 minutes to complete a procedure).

The work presented in this Thesis has evolved further. The 40 surgeons enrolled in the Thesis study were actually evaluated on 4 procedures (the fourth procedure was 4 compartment lower extremity fasciotomy) before and after and up to 18 months following ASSET training. For the larger US Army study, a total of 410 cadaveric procedures were evaluated on 106 different surgeons from more than 30 surgical training programs throughout the US. Twenty experts and thirty–five practising Consultant (Attending) surgeons were evaluated with the same standardized script as developed for the surgeons enrolled in the studies reported in this Thesis. Summary Figures showing the findings of the larger study are provided in in an Appendix VIII.

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APPENDICES: (references to Appendices are in Red in the Text)

Appendix I:

Transcribed Interview with expert Surgeon describing Femoral Artery Exposure and Control

Appendix II:

Standardized Scripts and Data Dictionary used for all Procedures and Definitions reported in the Thesis.

Appendix III:

Mobile App training program with screen shots

Appendix IV:

Evaluator Training Handbook

Appendix V:

Informed Consent Approved by University of Maryland Institutional Review Board and US Army Office of Human Research Protection

Appendix VI:

A demographics and experience questionnaire provided information on year of Residency and time since medical school graduation, as well as experience with upper and lower extremity trauma and their confidence level in performing upper and lower extremity surgical procedures.

Appendix VII:

Case Logs summary of low, moderate and high levels. Initial Management of Trauma patient experience

Appendix VIII:

Summary Figures showing the findings of the larger US Army funded study

APPENDICES:

Appendix I:
Transcribed Interview with expert Surgeon describing Femoral Artery Exposure and Control

Appendix II:
Standardized Scripts used for all Procedures reported in the Thesis with the exception of for blind video review.

Appendix III: Data Dictionary

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Appendix VI:
A demographics and experience questionnaire was completed requesting information on year of Residency and time since medical school graduation, as well as experience with upper and lower extremity trauma and their confidence level in performing upper and lower extremity surgical procedures.

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Case Logs summary of low, moderate and high levels. Initial Management of Trauma patient experience

Appendix VIII: Training for Data Collection App use

Appendix IX: Summary Figures showing the findings of the larger US Army funded study

Surgeon Interview on Common Femoral/Superficial femoral Exposure at Groin

(discussion of Colin Mackenzie with Sharon Henry a Professor of Trauma Surgery at the Shock Trauma Center in Baltimore) additional *comments in italics and parentheses made on review of original descriptions with Dr Henry*.

Key steps

1. If possible (injury may make this impossible) abduct and slightly externally rotate the thigh. *This brings the femoral artery nearer skin surface. Alternatively a pillow under the buttocks may achieve the same effect, but it may not be possible to optimally position the femoral artery to improve access.*
2. Palpate for pulse if present make vertical incision (*tradition is vertical to gain best access..sometimes call hockey stick 'incision'*) slightly lateral to the pulse and extend from above inguinal ligament for 10 cm (or more if needed) (*It is important to make the incision long enough so that all anatomy can be seen, especially in the obese or very muscular subjects*)
3. It is often to helpful to use a marker to outline the anatomic boundaries
4. When pulse is not palpable (*as is commonly the case in shock and injury*) 2 landmark based approaches are described
    A. Identify the pubic tubercle medially at the groin
        a. Make the incision two fingerbreadths lateral to the tubercle
        b. Extend it distally obliquely along the medial border of the Sartorius
    B. Identify the inguinal ligament*(important step as the incision has to go above inguinal ligament in order to gain vascular control of common femoral artery)*
        a. Laterally extends from Anterior superior iliac spine to medially pubic tubercle
        b. It is not the groin skin crease *(= beginners mistake)*
        c. The femoral triangle is at the midpoint of the inguinal ligament and the incision bisects it (*if incision too lateral can damage the femoral nerve, if too medial damage to the femoral vein*). (*Feel pulse, if palpable, directly over femoral artery or just lateral to pulse to make incision*)
            i. The boundaries of the femoral triangle (Scarpa's triangle) are
                1. Superiorly the inguinal ligament
                2. Laterally the Sartorius muscle
                3. Medially adductor longus muscle
5. Once the skin is incised there is fat and superficial fascia to dissect(*Fat and sometimes lymph nodes can make approach to femoral artery difficult)*
6. It is helpful to place a self retaining retractor in the wound to facilitate deeper dissection
7. There may be lymph nodes in the this tissue (*recognize lymphatics and ligate to prevent lymphocele complication)*
8. It should be swept medially (*as space over Femoral vein*)
9. Ligating lymphatics associated with lymph nodes can decrease postop lymph leak

10. Several venous branches may need to be divided and ligated as the femoral sheath is approached (These are accompanying veins to arterial branches listed below (superficial circumflex iliac vein etc) (*Also branch off femoral nerve can drape over femoral artery and can be damaged)*
11. These veins converge on the saphenofemoral junction (*finding this junction of superficial and deep veins can help the surgeon know where they need to be to approach the femoral artery)*
12. The deep fascia (fascia lata) is incised on the medial border of the Sartorius muscle
13. Sartorius is retracted laterally
14. The femoral vessels are located within the femoral sheath which is formed from the transversalis fascia
15. The sheath is opened anteriorly (*mostly other arterial branches do not come off the femoral artey anteriorly so if is safe to open the sheath anteriorly*)
16. Proximal branches may be encountered (circumflex iliac and superficial epigastric arteries (*these are near the inguinal ligament landmark)*)
17. The femoral vein is located medial to the femoral artery more distally it is positioned posterior to the artery.
18. The femoral nerve is located lateral to the artery
19. Branches of the common femoral artery include
    a. Superficial circumflex iliac
    b. Superficial eipigastric
    c. Superficial external pudendal artery
    d. Profunda femoris
20. The femoral artery is identified, dissected using metzenbaum scissors
21. The artery is mobilized using a right angle clamp and a vessel loop is placed around the vessel (*should be careful handling the artery with as little pick up as possible as it easily goes into spasm in the young patient making it difficult to repair, loop is placed twice around to control blood flow completely, once under only allows restriction of flow*)
22. The superficial femoral artery begins after the profunda branch takes of
    a. A caliber change is noted
    b. The Sup Fem Art is similarly dissected
23. The branch occurs about 3-5 cm distal to the inguinal ligament
24. The profunda femoris must be controlled
25. The profunda femoris is located posterolateral to the common femoral artery
26. Direct dissection of the artery is avoided to avoid injury to the lateral femoral circumflex vein which is nearby
27. To control the profunda femoris safely
    a. place vessel loop around common femoral artery
    b. place right angle beneath Sup Fem Art
    c. Pass one end of vessel loop to right angle below Sup Fem Art
    d. This controls the profunda
    e. The loop may be double repassing the loop to a right angle under the Common Fem Art

What differences in approach if time critical? One can always apply external pressure to control bleeding, or a tourniquest can occlude bleeding completely, so there should be no real time pressure, except in situations where the casualty is exsanguinating through other injuries. The branch of the femoral nerve draping over the artery maybe sacrificed if one was in a great hurry (see 10 above). Not only must one get control of the femoral artery, but must also control the profunda. One must not create more bleeding. Novice mistakes include making the incision in the wrong place, making it too small and 'digging" into muscle on the approach rather than pushing the muscle aside.

Name of Evaluator: **Date:**

Name of Candidate:

Case ONE: Axillary Artery, 1st Trial **(Circle timing): Pre Post**

Circle type of trial: Cadaver / Model

Narrative for Examiner: (Show case slides)

Case One:

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.**

Question #1. What are the structures you suspect <u>could</u> be injured along the path of the bullet?

Expected Answers checklist:

The participant described each of the following as potentially injured:		
	Yes	**No**
Axillary Artery		
Axillary Vein		
Brachial Plexus		
Lung		
Subclavian Artery		
Subclavian Vein		
Mediastinal structures		
Bones		

Question #2. What physical findings will you look for to help you decide which structures are injured? Include signs of vascular, thoracic, nerve, and bone injury.

Expected Answers checklist:

The participant describes each of the following physical findings and tests:		
	Yes	**No**
Decreased breath sounds		
Active arterial bleeding		
Enlarging or expanding Hematoma		
Absent distal pulses		
Distal Ischemia		
Bruit or palpable thrill		
- Indicates that any or all of above are "hard signs" of vascular injury		
Active venous bleeding		
Unequal blood pressure, decreased Brachial-Brachial Index		
Doppler pulses—diminished flow		
Sensory loss		
Loss of motor function – weakness, inability to move arm		
Bony instability, deformation, crepitus		
Sub-cutaneous air		
Tracheal deviation		

The patient's blood pressure is 85/65 and HR 110 and is unable to move his arm, has decreased sensation and absent brachial, radial, and ulnar pulses.

Question #3:
What additional studies would you perform to help you identify or rule out specific injuries in this patient?

Expected Answers checklist:

The participant described each of the following as additional studies		
	Yes	No
FAST exam to look for pericardial tamponade, hemothorax, pneumothorax		
Chest X-ray		
A marker (eg paperclip) is placed to mark wound prior to x-ray		
Error: Fails to obtain CXR		
CT of Chest (zero points)		
CT Angiogram (zero pts)		
Angiogram (zero points)		
Error: Inappropriate use of CT or Angio*		

****All of the above tests are acceptable possible studies but the participant should clearly indicate these tests <u>should only be done in a hemodynamically stable patient</u>. Without this qualifier, performing any of these tests prior to taking this patient to the OR has potential for negative outcome & should result in negative value scoring.***

***Scoring Note: no additional points are added for additional studies**

[Advance slide to show Chest x-ray]

A chest x-ray has been obtained and shows no evidence of hemo or pneumothorax. There is a bullet fragment adjacent to the mid-portion of the ipsilateral scapula just superficial to the skin of the back – In other words a bullet trajectory from front to back on the same side, which does NOT involve the thoracic cavity. **Now the BP is 89/69 HR is 110. There is no other obvious trauma and his hand is cool and pale.**

Question #4:

Now that you have seen the wound, physical findings, and chest x-ray, what is your plan for this patient?

If the participant suggests a non-operative course – they should be informed that: **the patient is now in the operating room and needs exposure and control of the axillary artery.**

Expected Answers checklist:

The participant states the following plan		
	Yes	**No**
Patient should be taken urgently to the Operating room		
Error: Delay in going to the operating room		

Question #5:

What is your plan to resuscitate this patient? Include fluids or medications you would use during the initial resuscitation.

Expected Answers checklist:

The participant describes each of the following additional items the patient might receive:		
	Yes	**No**
Resuscitate with blood products		
Transfuse with high ratio of blood:FFP:platelets/ Massive transfusion protocol		
Minimize crystalloid infusion		
Limit volume resuscitation until bleeding controlled		
Do not delay surgery for resuscitation, resuscitate in OR		
Give TXA		
Large bore IV access		

The patient has now been transported to the Operating Room and is on the OR table in front of them.

Question OR # 1:

How would you position and prep this patient in order to repair this injury and explain why you chose to prep as you did?

Expected Answers checklist:

The participant Indicates the following in response:		
	Yes	**No**
The patient should be supine		
The arm extended on an arm board		

The prep should include:		
The Entire Chest		
States possible need for sternotomy for proximal control		
The Entire arm and hand on the affected side		
States need to evaluate perfusion to the hand		
The thigh/groin for possible vein harvest		
The neck		
States possible need to expose subclavian artery for proximal control		
Error: Fails to prep entire chest		
Error: Fails to prep entire arm and hand.		
Error: Fails to prep the thigh for vein harvest		

Question OR # 2:

At this time, please describe and then mark on the skin the landmarks and the incision that you plan to use.

Expected Answers checklist:

The participant Indicates the following in response:		
	Yes	**No**
The sternal notch		
The clavicle		
The deltopectoral groove		
Incision runs from mid-clavicle laterally in deltopectoral groove.		

EXPOSURE OF AXILLARY ARTERY

"Now I would like you to get control of the Axillary Artery proximal to the wound by dissecting and placing a vessel loop around the artery. As you operate, speak out loud and identify each step of the procedure. It is not necessary to rush through the procedure—you should operate at a comfortable pace. The procedure will be deemed complete once you have placed a vessel loop around the axillary artery to obtain proximal control. Do you have any questions? If not please proceed."

Expected operative dissection performance checklist:

The participant describes and performs each of the following steps:			
	Yes	**No**	**Time**
Initial skin incision is adequate to perform exposure			**Start Incision**
Splitting or dividing Pectoralis Major			**Start Dissection**
Divides Pectoralis Minor			
Correctly identifies Axillary Artery			
Correctly identifies Axillary Vein			
Correctly identifies brachial plexus			
Controls the Axillary Artery Proximal to injury			**Finish**
Error: Incorrectly identifies the Axillary artery and does not recognize or correct error			
Error: Incorrectly identifies the Axillary Artery but is able to recognize and correct			

Technique points

	Score 1-5
*Exposes arteries by dissecting directly on anterior surface**	
*Manipulates artery by grasping adventitia**	
Uses instruments properly	
Positions body to use instruments to best advantage	
Proceeds at appropriate pace with economy of movement	
Handles tissue well with minimal damage	
Creates an adequate visual field for procedure	
Communicates clearly and consistently	
Performs procedure without unnecessary dissection	
Continually progresses towards the end goal	

(5) Every time/Excellent; (4) Almost every time/Very good; (3) Sometimes/Good; (2) Rarely/Fair; (1) Never/Poor

*N/A for model

Expert Discriminator Operative Field Maneuvers for Axillary Artery Exposure

	Yes	No
Operates through 'key-hole' or too small a skin incision		
Operates using full incision		
Excessive dissection		
Pointless digging and shifting around in surgical field		
Has a logical operating sequence		
Lacks anatomical knowledge		

Expert Discriminatory Instrument Use for Axillary Artery Exposure

	Yes	No
Improper instrument use (e.g. back-handed use)		
Incorrect instrument holding (e.g. forceps too near tips, thumb through scissors handle)		
Scalpel use: multiple tentative cuts or cuts tangentially		
Switches instruments more than you would		
Uses scissors less than you would		
Dedicated use of a single instrument.		

Questions in OR, after dissection:

What are the consequences of ligating the axillary artery?

The participant answered the questions correctly:		
	Yes	No
Ligation of the axillary generally does not cause ischemia due to extensive collaterals around the shoulder.		

What are the pitfalls or common errors that one might expect with this procedure?

Possible Answers		
	Yes	No
Incision – too high, too low		
Iatrogenic injury to nerve, artery, vein		
Inability to get proximal control – needing to go above clavicle or into chest		
Diving into clot or hematoma without adequate control		
Mistaking nerve for artery		
Incision – too high, too low		

AXILLARY ARTERY EXPOSURE GLOBAL RATING (circle one)**:**

Technical Skills for Exposing Axillary Artery:

1	2	3	4	5
The participant's technical skills were well below expected with much wasted moves and very poor tissue handling.	The participant demonstrated below average technical skills with lots of wasted movements and errors in tissue handling.	The participant demonstrated average technical skills with some 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 superior technical skills with no wasted movements and proper respect for tissues.

Overall Understanding of the Surgical Anatomy of the Axillary Region:

1	2	3	4	5
Inadequate knowledge of the regional anatomy. Unable to identify major structures and their relationships.	Knowledge of regional anatomy is below average. Can name most of the major structures but, requires some prompting.	Average understanding of the anatomy. May not be able to immediately point out or name all of the structures but can do so with minimal prompting.	Above average understanding of anatomy. Able to point out all of the relevant structures without prompting.	Superior grasp of anatomy and knows the minutia. Should be teaching anatomy class.

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

1	2	3	4	5
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.

Evaluator's overall rating (1-100) ______________________________

≥ 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!

The overall score should be the instructor's subjective rating of how well the surgeon performed. This will be compared to the objective score for the purpose of validating the scoring method.

Body Habitus of cadaver (Circle):

Obese   Average   Thin

Cadaver Anatomy (Circe):

Normal   Variant

Name of Evaluator: Date:

Name of Candidate:

Case ONE: Brachial Artery, 1st Trial **(Circle timing): Pre Post**

Circle type of trial: Cadaver / Model

Narrative for Examiner: (Show case slides)

Case Two

Case Presentation

- **32 y/o male was accidentally shot in the arm at close range with a hunting rifle.**
- **He was reported to have had large pulsatile blood loss at the scene.**

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

- **There is active pulsatile bleeding from the medial wound which is currently being controlled with direct pressure by the paramedic.**
- **Distal pulses are absent.**
- **BP = 100/68, HR = 120**
- **There are no other injuries.**

Question #1:

What are the structures you suspect <u>could</u> be injured, including nerve, artery, vein, or other?

Expected Answers checklist:

The participant described each of the following as potentially injured:		
	Yes	**No**
Brachial Artery		
Median Nerve		
Radial Nerve		
Humerus		
Radius, Ulna		
Veins		

BP is 105/70 and HR is 110. The patient has no neurologic deficit, but has absent radial and ulnar pulses.

Question #2:

What additional studies would you perform to help you identify or rule out specific injuries in this patient?

Expected Answers checklist:

The participant described each of the following as additional studies		
	Yes	**No**
X-ray of arm		
Chest X-ray		
CT Angiogram (zero pts)		
Angiogram (zero points)		
Error: Inappropriate use of CT or Angio*		

****All of the above tests are acceptable possible studies but the participant should clearly indicate these tests <u>should only be done in a hemodynamically stable patient</u>. Without this qualifier, performing any of these tests prior to taking this patient to the OR has potential for negative outcome & should result in negative value scoring.***

***Scoring Note: no additional points are added for additional studies**

The participant should be informed that the X-ray shows no fracture and no retained fragments. Chest X-ray is normal (if ordered).

Question #3:

What is your plan for this patient?

If the participant persists in suggesting a non-operative course – they should be informed that **"the patient is now in the operating room."**

Expected Answers checklist:

The participant states the following plan		
	Yes	**No**
Patient should be taken urgently to the Operating room		
Error: Delay in going to the operating room		

The Participant should be told that the Patient has now been transported to the Operating Room and is on the OR table in front of them.

Question OR # 1:

How would you position and prep this patient in order to repair this injury and explain why you chose to prep as you did?

Expected Answers checklist:

The participant Indicates the following in response:		
	Yes	No
The patient should be supine		
The arm extended on an arm board		

The prep should include:		
The Entire Chest and hand on the affected side		
Mentions need to evaluate perfusion to the hand		
The Axilla on the affected side		
Mentions possible need to expose axillary artery for proximal control		
The thigh/groin for possible vein harvest		
Error: Fails to prep entire arm and hand.		
Error: Fails to prep the thigh for vein harvest		

Question OR # 2:

Can you describe how you plan to gain control of the bleeding vessel using general principles of vascular surgery?

Expected Answers checklist:

The participant indicates the following principles of vascular exposure:		
	Yes	No
Proximal control first		
Distal control second		
Expose injury		

Question OR # 3:

At this time, please describe and then mark on the skin the landmarks and the incision that you plan to use.

Expected Answers checklist:

The participant Indicates and marks the following landmarks:		
	Yes	**No**
The biceps and triceps		
The humerus		
Incision between biceps and triceps bellies		

EXPOSURE OF BRACHIAL ARTERY

"Now I would like you to surgically expose and control the Brachial Artery with a vessel loop in order to gain proximal control. As you operate, speak out loud and identify each step of the procedure. It is not necessary to rush through the procedure. The procedure will be deemed complete once you have placed a vessel loop around the Brachial artery to obtain proximal. Do you have any questions? If not please proceed"

Expected operative dissection performance checklist:

The participant describes and performs each of the following steps:			
	Yes	**No**	**Time**
Initial skin incision is adequate to perform exposure			**Start Incision**
Creates a plane of dissection between the Biceps and Triceps			**Start Dissection**
Correctly identifies Median Nerve			
Retracts and protects Median Nerve			
Correctly identifies Brachial Artery			
Dissects Brachial Artery away from venae comites			
Controls Brachial artery with vessel loop			**Finish**
Error: Incorrectly identifies the brachial artery and does not recognize or correct error			
Error: Incorrectly identifies the Axillary Artery but is able to recognize and correct			

Technique points

	Score 1-5
*Exposes arteries by dissecting directly on anterior surface**	
*Manipulates artery by grasping adventitia**	
Uses instruments properly	
Positions body to use instruments to best advantage	
Proceeds at appropriate pace with economy of movement	
Handles tissue well with minimal damage	
Creates an adequate visual field for procedure	
Communicates clearly and consistently	
Performs procedure without unnecessary dissection	
Continually progresses towards the end goal	

(5) Every time/Excellent; (4) Almost every time/Very good; (3) Sometimes/Good; (2) Rarely/Fair; (1) Never/Poor

*N/A for model

Expert Discriminator Operative Field Maneuvers for Axillary Artery Exposure

	Yes	No
Operates through 'key-hole' or too small a skin incision		
Operates using full incision		
Excessive dissection		
Pointless digging and shifting around in surgical field		
Has a logical operating sequence		
Lacks anatomical knowledge		

Expert Discriminatory Instrument Use for Axillary Artery Exposure

	Yes	No
Improper instrument use (e.g. back-handed use)		
Incorrect instrument holding (e.g. forceps too near tips, thumb through scissors handle)		
Scalpel use: multiple tentative cuts or cuts tangentially		
Switches instruments more than you would		
Uses scissors less than you would		
Dedicated use of a single instrument.		

Questions in OR, after dissection:

What are the consequences of ligating the brachial artery?

The participant answered the questions correctly:		
	Yes	No
Can ligate the brachial artery: ligation above the profunda results in limb loss in 50% of cases; below the profunda results in limb loss in 5% of cases		

What are the pitfalls or common errors that one might expect with this procedure?

Possible Answers		
	Yes	No
Incision – too high, too low		
Latrogenic injury to nerve, artery, vein		
Diving into clot or hematoma without adequate control		
Mistaking nerve for artery		
Diving into clot or hematoma at the injury site without adequate control		

BRACHIAL ARTERY EXPOSURE GLOBAL RATING (circle one)**:**

Technical Skills for Exposing Brachial Artery:

1	2	3	4	5
The participant's technical skills were well below expected with much wasted moves and very poor tissue handling.	The participant demonstrated below average technical skills with lots of wasted movements and errors in tissue handling.	The participant demonstrated average technical skills with some 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 superior technical skills with no wasted movements and proper respect for tissues.

Overall Understanding of the Surgical Anatomy of the Brachial Region:

1	2	3	4	5
Inadequate knowledge of the regional anatomy. Unable to identify major structures and their relationships.	Knowledge of regional anatomy is below average. Can name most of the major structures but, requires some prompting.	Average understanding of the anatomy. May not be able to immediately point out or name all of the structures but can do so with minimal prompting.	Above average understanding of anatomy. Able to point out all of the relevant structures without prompting.	Superior grasp of anatomy and knows the minutia. Should be teaching anatomy class.

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

1	2	3	4	5
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.

Evaluator's overall rating (1-100) ______________________________

≥ 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!

The overall score should be the instructor's subjective rating of how well the surgeon performed. This will be compared to the objective score for the purpose of validating the scoring method.

Body Habitus of cadaver (Circle):

Obese Average Thin

Cadaver Anatomy (Circe):

Normal Variant

Name of Evaluator: **Date:**

Name of Candidate:

Case ONE: Femoral Artery, 1st Trial **(Circle timing): Pre Post**

Circle type of trial: Cadaver / Model

Narrative for Examiner: (Show case slides)

Case Three

Case History:

- **24 y/o male who was a victim of a drive by shooting, sustaining a through and through gunshot wound to the Right/Left mid-thigh**
- **He was reported to have a large amount of bright red pulsatile blood at the scene**
- **He was initially taken to a small community hospital without an in-house surgeon where his blood pressure was 80/50 and his heart rate was 140. He was reported to have a markedly swollen thigh with active bleeding and no distal pulses. There are no other injuries.**

[Advance slide to show image of wound]

[Advance slide to continue narrative]

- **At the outside hospital a tourniquet was placed and he received 3000 cc of crystalloid. He is transferred to your facility now more than four hours after the injury with a blood pressure of 100/70 and a HR of 130, with a markedly swollen thigh and absent distal pulses.**

Question #1:

What are all the structures you suspect could be injured, including nerve, artery, vein, or other structure?

Expected Answers checklist:

The participant described each of the following as potentially injured:		
	Yes	**No**
Common Femoral Artery		
Common Femoral Vein		
Superficial Femoral Artery		
Superficial Femoral Vein		
Femoral Nerve/Branches		
Profunda Femoral Artery		
Femur		

Question #2:

What are the physical findings that may help you determine which structures are injured in this patient, including signs of vascular, nerve, and bone injury?

Expected Answers checklist:

The participant describes each of the following physical findings and tests:		
	Yes	**No**
Loss of Popliteal/DP/PT pulses		
Pulsatile bleeding		
Expanding hematoma		
Hemorrhagic shock		
Unstable femur or crepitance of bone		
Ankle-Ankle or Ankle-Brachial Index		
Neurologic deficits in femoral nerve distribution:		
Sensation to anterior thigh		
Motor to hip flexion, knee extension		

BP is 95/65 and HR is 125. The patient has a cool and pulseless foot, he is able to move the ankle and foot, but is unable to extend the knee. There is numbness on the anterior thigh.

Question #3:
What additional studies would you perform to help you identify or rule out specific injuries in this patient?

Expected Answers checklist:

The participant described each of the following as additional studies		
	Yes	**No**
X-ray of femur		
Chest X-ray (zero points)		
CT Angiogram (zero pts)		
Angiogram (zero points)		
Error: Inappropriate use of CT or Angio*		

All of the above tests are acceptable possible studies but the participant should clearly indicate these tests <u>should only be done in a hemodynamically stable patient</u>. Without this qualifier, performing any of these tests prior to taking this patient to the OR has potential for negative outcome & should result in negative value scoring.

***Scoring Note: no additional points are added for additional studies**

The femoral X-ray shows no fracture and no retained fragments. Chest X-ray is normal (if obtained).

*****If Sup Femoral artery injury has not been recognize—Tell the participant explicitly that the patient has an injury to the Superficial Femoral Artery.***

Question #4:
What is your plan for this patient?

FYI: If the participant persists in suggesting a non-operative course – **Inform the participant that the patient is now in the operating room and needs exposure and control of the Femoral Artery.**

Expected Answers checklist:

The participant states the following plan		
	Yes	**No**
Patient should be taken urgently to the Operating room		
Error: Delay in going to the operating room		

Question #5:

What interventions are important to resuscitate and treat this patient before and during surgery?

Question #6:

What further management would you consider given the ischemic time which is already greater than 4 hours?

Expected Answers checklist:

The participant describes each of the following additional items the patient might receive:		
	Yes	**No**
Hemorrhagic Shock:		
Resuscitate with blood products		
Transfuse with high ratio of blood:FFP:platelets/ Massive transfusion protocol		
Wean off norepinephrine		
Minimize crystalloid		
Give TXA		
Reperfusion injury:		
Volume load		
Bicarbonate		
Monitor for arrhythmia		
Already lengthy ischemic time:		
Temporary vascular shunt		
Recognize need for fasciotomy		
Monitor for rhabdomyolysis		

The patient has now been transported to the Operating Room and is on the OR table in front of you.

Question OR # 1:

How would you position and prep this patient in order to repair this injury and explain why you chose to prep as you did?

Expected Answers checklist:

The participant Indicates the following in response:		
	Yes	**No**
The patient should be supine		
Leg externally rotated and knee supported		

The prep should include:		
The entire lower extremity, including foot on the affected side		
States need to assess perfusion to the foot		
States possible need for fasciotomy		
The thigh/groin on the contralateral side for possible vein harvest		
Error: Fails to prep entire lower extremity, including foot on effected side		
Error: Fails to prep the contralateral groin		

Question OR # 2:

At this time, please verbalize and then mark on the cadaver the landmarks and the incision that you will use on the skin.

Expected Answers checklist:

The participant Indicates and marks the following landmarks		
	Yes	**No**
Pubic tubercle		
Ant Sup iliac Spine (ASIS)		
Inguinal ligament		
Femoral artery (approximate location 1/3 of distance from pubic tubercle to ASIS)		
Marks longitudinal incision over femoral artery, 2 finger breadths lateral to the pubic tubercle		
Incision extends above inguinal ligament 4-5 cm		

<u>EXPOSURE OF FEMORAL ARTERY</u>

"At this time, I would like you to surgically explore and control the Common Femoral Artery, the Superficial Femoral Artery, and Profunda Femoral Artery. As you operate, <u>speak out loud</u> and identify each step of the procedure. It is not necessary to rush through the procedure. The procedure will be deemed complete once you have placed a double vessel loop around the Common Femoral, Superficial Femoral, and Profunda Femoral arteries to obtain proximal control. Do you have any questions? If not please proceed."

Expected operative dissection performance checklist:

The participant describes and performs each of the following steps:			
	Yes	**No**	**Time**
Initial skin incision is adequate to perform exposure			**Start Incision**
Correctly identifies Common Femoral Artery			**Start Dissection**
Correctly identifies Common Femoral Vein			
Correctly identifies Profunda Femoral Branch			
Correctly identifies Superficial Femoral Artery			
Controls Common Femoral Artery with vessel loop			
Controls Profunda Femoral Artery with vessel loop			
Controls Superficial Femoral Artery with vessel loop			**Finish**
Error: Incorrectly identifies the CFA, SFA, or PFA and does not recognize or correct error			
Error: Incorrectly identifies CFA, SFA, or PFA, but is able to recognize and correct			

Technique points

	Score 1-5
*Exposes arteries by dissecting directly on anterior surface**	
*Manipulates artery by grasping adventitia**	
Uses instruments properly	
Positions body to use instruments to best advantage	
Proceeds at appropriate pace with economy of movement	
Handles tissue well with minimal damage	
Creates an adequate visual field for procedure	
Communicates clearly and consistently	
Performs procedure without unnecessary dissection	
Continually progresses towards the end goal	

(5) Every time/Excellent; (4) Almost every time/Very good; (3) Sometimes/Good; (2) Rarely/Fair; (1) Never/Poor

*N/A for model

Expert Discriminator Operative Field Maneuvers for Axillary Artery Exposure

	Yes	No
Operates through 'key-hole' or too small a skin incision		
Operates using full incision		
Excessive dissection		
Pointless digging and shifting around in surgical field		
Has a logical operating sequence		
Lacks anatomical knowledge		

Expert Discriminatory Instrument Use for Axillary Artery Exposure

	Yes	No
Improper instrument use (e.g. back-handed use)		
Incorrect instrument holding (e.g. forceps too near tips, thumb through scissors handle)		
Scalpel use: multiple tentative cuts or cuts tangentially		
Switches instruments more than you would		
Uses scissors less than you would		
Dedicated use of a single instrument.		

Questions in OR, after dissection:

What are the consequences of ligating the Superficial Femoral artery? What are the consequences of ligating the Superficial Femoral vein?

The participant answered the questions correctly:		
	Yes	No
SFA results in severe limb ischemia /requires amputation		
SFV ligation may cause limb edema		

What are the pitfalls or common errors that one might expect with this procedure?

Possible Answers		
	Yes	No
Incision – too high, too low		
Iatrogenic injury to nerve, artery, vein		
Inability to get proximal control below the inguinal ligament		
Diving into clot or hematoma at the injury site without adequate proximal and distal control		
Mistaking nerve for artery		
Variable location of Profunda Femoral Artery or mistaking SFA for CFA		

FEMORAL ARTERY EXPOSURE GLOBAL RATING (circle one):

Technical Skills for Exposing Axillary Artery:

1	2	3	4	5
The participant's technical skills were well below expected with much wasted moves and very poor tissue handling.	The participant demonstrated below average technical skills with lots of wasted movements and errors in tissue handling.	The participant demonstrated average technical skills with some 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 superior technical skills with no wasted movements and proper respect for tissues.

Overall Understanding of the Surgical Anatomy of the Femoral Region:

1	2	3	4	5
Inadequate knowledge of the regional anatomy. Unable to identify major structures and their relationships.	Knowledge of regional anatomy is below average. Can name most of the major structures but, requires some prompting.	Average understanding of the anatomy. May not be able to immediately point out or name all of the structures but can do so with minimal prompting.	Above average understanding of anatomy. Able to point out all of the relevant structures without prompting.	Superior grasp of anatomy and knows the minutia. Should be teaching anatomy class.

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

1	2	3	4	5
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.

Evaluator's overall rating (1-100) ______________________________

≥ 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!

The overall score should be the instructor's subjective rating of how well the surgeon performed. This will be compared to the objective score for the purpose of validating the scoring method.

Body Habitus of cadaver (Circle):

Obese Average Thin

Cadaver Anatomy (Circe):

Normal Variant

Data documentation for Retention and Assessment of Surgical Performance data

Contents (click to go page)

To find a given procedure, seek with these values starting with the procedure type or ALL for full session videos.

There are 5 elements to the video file names, separated by space or underscore and then ending with the extension, MPG or WMV. For example: 21_AA_1_CAD_H.mpg These 5 elements indicate the surgeon ID, procedure content, script version, patient model type and primary camera for the video file.

The first element is the participant RASP ID number (in our example: 21, which is within the range for Phase 2)
Phase 1 Expert preliminary participants RASP IDs 00-10 script=0
Phase 1 Novice preliminary participants RASP IDs 11-20 script=0
Phase 2 Asset student RASP IDs 21-76 Scripts=1, 2, 3, 4
Phase 3 Asset student RASP IDs 101-139 Scripts=4, 5
Expert Series 200 IDs 201-211 Script 2

The second element of the video file name is the content, a surgical procedure:
AA, BA, FA, FAS, CA, or ALL
AA=Axillary Artery
BA=Brachial Artery
FA=Femoral Artery
ALL=All procedures performed in a single script session

The third element of the video file name is the number of the script, 0 through 5
0=preliminary trial script
1=pre-training
2=post-training
3=post-training abridged
4=retention
5-retention abridged

The fourth element of the video file name is the model type
CAD = cadaver
MOD = Simulation Model

The fifth element of the video file name is the camera type
H = surgeon's head camera
P = PTZ mounted in ceiling overhead
X = Phase 1 either camera used in clips

Where camera data is missing, other cameras, including a wall-mounted camera, might be used to substitute all or part of the missing time for either of the two camera types.

Important! Please read before accessing data.

All original RASP raw or "Mother" data and videos are available. For further information contact kpugh@stapa.umm.edu or ggranite@stapa.umm.edu

Data is organized to match its location in the 'full' script

Note #1:

There are five versions of RASP data:

- Raw or "Mother" data→ Original data with known errors fixed (repeat evaluation deleted, cloud data error addressed)
- Daughter data→ Recoded data with ALL scores and responses from both evaluators
- Summary data→ Recoded data with summary measures scores from both evaluators
- Mean data→ Recoded data with mean scores calculated by combining scores from both evaluators. This data set also contains the trauma readiness index

  Note: some graphs use Mean data and others (errors) use Daughter data.
- Trauma Readiness Index (see note #3 below)

Note #2

Surgeons recruited as Phase 2 novices performed two sets of procedures at their post (ASSET + 2 weeks) and follow-up ((ASSET + 18 months) using cadavers and the simulated model. The order of procedures (cadaver or model first) was randomly assigned for each surgeon. For all surgeons, the first or 'full' script evaluation included four procedures and 'extra' questions not asked to avoid repetition in the second or abridged evaluation.

Note #3:

Trauma readiness Index (TRI) is the mean of all IPS scores calculated using the 'Mean' data set. TRI is calculated only for surgeons who had a full set of evaluations (AA, BA, FA, and FAS) (n=228). For example, TRI is provided for cadaver for a retention visit only if we have complete data for ALL four procedures. Four values for TRI are given:

- TRI for vascular procedures with errors and time included
- TRI for ALL procedures (including Fasciotomy) with errors and time included
- Adjusted vascular TRI (TRI without time or errors included)
- Adjusted TRI for all procedures.

Note #4:

For simulated models the IPS does not include items in the scripts that were not recorded for models. Specifically, the following three items are excluded from IPS calculations for simulated models in Axillary, Brachial and Femoral artery exposures:

- Exposes artery by dissecting directly on anterior surface
- Manipulates by grasping adventitia
- Uses instruments properly

Note #5:

All experts are set at 60 months since ASSET training

Data Dictionary

Location in data	Possible values	Definitions
Recoded values common to all data	N/A =997	All 'extra' questions only asked in the 'full' script will be marked as non-applicable N/A (or 997) in the abridged data.
Recoded values common to all data	Surgeon_id	A unique numeric identifier assigned to each surgeon.
Recoded values common to all data	Evaluator_group	Character variable identifying type of evaluator anatomist or surgeon. Previously Jr vs. Sr.
Recoded values common to all data	Evaluator_ID ## = N(1 to 23) Doe=999	"Doe' = Senior vs. Junior status and evaluator identity unknown. This occurred as a result of tablet upload or log-in errors (n=60).
Source	AA_full AA_abridged BA_full BA_abridged FA_full FA_abridged FAS_full FAS_abridged	Procedure Type ● Axillary artery (AA) ● Brachial Artery (BA) ● Femoral artery (FA) ● Lower extremity fasciotomy (FAS) ● Carotid Artery (CA) Script type (see note 1 above) There are two versions of the main survey ● Abridged= technical skills/surgery ● Full= technical skills/ surgery + knowledge + non-technical skills
Study_arm	1_novice 2_expert 2_pre 2_post 2_18mfollowup 3_retention	#_abcdef ● # = phase ● abcdef= surgeon expertise level/ stage of study
Question responses	Correct responses or error present 1= Yes 0=No	For all questions, responses and errors were entered as present (1) or absent (0)
Question scores nomenclature (available on demand)	XY_Q#_score XY_Q#_possible	● XY= procedure type ● Q#= question number in full script ● Q#_score= sum(bold_score, notbold_score, bold_error_score, notbold_error_score) ● Possible= maximum score possible given the available non-missing responses = (#bold questions answered *2) + (# non-bold questions answered *1)
Component nomenclature	Subjective score Objective score	● Subjective score (evaluator rating) is a measure given by the evaluator based on their appraisal of how well a surgeon performed

	Adjusted score
	Possible Objective Score
	Old_IPS
	XY_IPS_with_time
	XY_IPS_adjusted
	
	COMPONENTS
	Knowledge scores
	    Anatomy
	    Management
	    General
	    All
	Procedure scores
	    Technical
	    Expert discriminators
		a procedure (out of 100)
		
		• Objective score is based on actual scores for procedure questions and errors. Mean scores were used for all 'extra' questions asked in full scripts and not asked in abridged
		
		• Adjusted score is based on actual scores for procedure questions **without errors**. Mean scores were used for all 'extra' questions asked in full scripts and not asked in abridged
		
		• XY_IPS_with_time= (XY_objective_score + XY_time_left) / (XY_possible_objective_score +**20**)
		
		• XY_IPS_adjusted= XY_adjusted_score/ XY_possible_objective_score
		Note: the objective score is a combination of procedure scores minus accumulated errors. The adjusted score excludes errors. Therefore IPS_adjusted is IPS without time and errors.
		
		• Old_XY_IPS= individual procedure score for AA as calculated in original Mother data (by EG)
		
		• Components (knowledge, anatomy, management, expert discriminators and technical) were derived from the color key used in the original mother data (see below) and **include errors**.
		For component scores that use only 'extra' questions found in the full script (for example XY_know_anatomy_score), these scores will be the same for both evaluators (because they are calculated using mean scores). Component scores with actual procedure scores (questions found in both full and abridged scripts) will differ by evaluator.
		• Know_anatomy= KA / dark green with blue
		• Know_manage= KI/ pink with blue
		• Know_general= K/ just blue without other colors
		• All_know= all K questions
		• All_anatomy= all A questions
		• Technical_anatomy= TA/ orange with dark green
		• Expertdis= TP/ purple/ expert discriminators
		• AA_technical= technical anatomy + expert discriminators

Component key

K	Knowledge
A	Anatomy
I	Management

T	Procedure (technical)
TP	Expert Discriminators

Note: Component are not mutually exclusive (can overlap). For example, knowledge K has questions which are also anatomy or management. The All_Anatomy scores are a combination of All these K questions.

Specific procedure components are detailed below.

Axillary Artery		
K	A	Question 1: What structures could be injured?
K	I	Question 2: What are the physical findings?
K	I	Question 3: Any additional studies?
K		Question 4: What is your plan?
K		Question 5: What is your plan to resuscitate?
K	A	Question 6 (OR#1): How would you position?
T	A	Question 7(OR#2): What are the landmarks?
T	A	Question 8: Performance checklist?
TP		Question 8(section 2): Technique Points?
TP		Question 9: Expert Discriminators?
TP		Question 10: Expert Discriminators?
K	A	Question 11: What are the consequences?
K	A	Question 12: What are the pitfalls?

Brachial Artery		
K	A	Question 1: What structures could be injured?
K	I	Question 2: Any additional studies?
K		Question 3: What is your plan?
K	A	Question 4 (OR#1): How would you position?
K	I	Question 5 (OR#2): How do you plan to gain control?
T	A	Question 6: What are the landmarks?
T	A	Question 7: Performance checklist?
TP		Question 7(section 2): Technique Points?
TP		Question 8: Expert Discriminators?
TP		Question 8(section 2): Expert Discriminators?
K	A	Question 10: What are the consequences?
K	A	Question 11: What are the pitfalls?

Femoral Artery		
K	A	Question 1: What structures could be injured?
K	I	Question 2: What are the physical findings?
K	I	Question 3: Any additional studies?
K		Question 4: What is your plan?
K	I	Question 5: Interventions/systemic consequences/ further management?
K	A	Question 6 (OR#1): How would you position?
T	A	Question 7 (OR#2): What are the landmarks?
T	A	Question 8: Performance checklist?
TP		Question 8(section 2): Technique Points?
TP		Question 9: Expert Discriminators?
TP		Question 9(section 2): Expert Discriminators?
K	A	Question 11: What are the consequences?
K	A	Question 12: What are the pitfalls?

Errors Classifications

Axillary Artery

Critical Technique Error

Fails to loop vessel proximal to injury **OR**

Time duration is greater than or equal to 20 minutes

Critical Management Error

Delay going to the OR **OR**

Inappropriate use of CT scan or Angiogram

Non-Critical/Morbidity/Other Management Error

Fails to obtain chest x-ray **OR**

Fails to prep entire chest **OR**

Fails to prep entire arm/hand **OR**

Fails to prep the thigh for vein harvest

Brachial Artery

Critical Technique Error

Fails to loop vessel proximal to injury **OR**

Time duration is greater than or equal to 20 minutes

Critical Management Error

Delay going to the **OR**

Inappropriate use of CT scan or Angiogram

Non-Critical/Morbidity/Other Management Error

Fails to prep entire arm/hand **OR**

Fails to prep the thigh for vein harvest

Femoral Artery

Critical Technique Error

Fails to loop vessel (CFA or SFA+PFA) proximal to injury **OR**

Time duration is greater than or equal to 20 minutes

Critical Management Error

Delay going to the OR **OR**

Inappropriate use of CT scan or Angiogram

Non-Critical/Morbidity/Other Management Error

Fails to prep entire lower extremity

Fails to prep the contralateral groin

Axillary Artery

Component name	**Description**
AA_objective_score	AA_objective_score= AA_Q1_mean_score + AA_Q2_mean_score + AA_Q3_mean_score + AA_Q4_mean_score + AA_Q5_mean_score + AA_Q6_mean_score + AA_Q7_score + AA_Q8_score + AA_Q8_expdis_score + AA_Q9_score + AA_Q10_score + AA_Q11_mean_score + AA_Q12_mean_score
AA_possible_objective_score	AA_possible_objective_score= AA_Q1_possible_mean + AA_Q2_possible_mean + AA_Q3_possible_mean + AA_Q4_possible_mean + AA_Q5_possible_mean + AA_Q6_possible_mean + AA_Q7_possible + AA_Q8_possible + AA_Q8_expdis_possible + AA_Q9_possible + AA_Q10_possible + AA_Q11_possible_mean + AA_Q12_possible_mean
AA knowledge	AA_know_anatomy_score= AA_Q1_mean_score + AA_Q6_mean_score + AA_Q11_mean_score + AA_Q12_mean_score; AA_know_anatomy_possible= AA_Q1_possible_mean + AA_Q6_possible_mean + AA_Q11_possible_mean + AA_Q12_possible_mean; AA_know_anatomy_percent= AA_know_anatomy_score/ AA_know_anatomy_possible; AA_know_manage_score= AA_Q2_mean_score + AA_Q3_mean_score; AA_know_manage_possible= /*questions with knowledge and management/ I/ pink*/ AA_Q2_possible_mean +

	AA_Q3_possible_mean; AA_know_manage_percent = AA_know_manage_score/ AA_know_manage_possible; AA_know_general_score= AA_Q4_mean_score + AA_Q5_mean_score; AA_know_general_possible= /*questions with just knowledge - blue*/ AA_Q3_possible_mean + AA_Q4_possible_mean; AA_know_general_percent= AA_know_general_score/ AA_know_general_possible; AA_all_know_score= AA_know_anatomy_score + AA_know_manage_score + AA_know_general_score/*all knowledge or K*/ AA_all_know_possible= AA_know_anatomy_possible + AA_know_manage_possible + AA_know_general_possible
AA anatomy	/*all anatomy*/ AA_all_anatomy_score= AA_know_anatomy_score + AA_technical_anatomy_score; AA_all_anatomy_possible= AA_know_anatomy_possible + AA_technical_anatomy_possible; AA_all_anatomy_percent= AA_all_anatomy_score/ AA_all_anatomy_possible;
Technical procedure scores	AA_technical_anatomy_score= AA_Q7_score + AA_Q8_score; AA_technical_anatomy_possible= AA_Q7_possible + AA_Q8_possible; AA_technical_anatomy_percent= AA_technical_anatomy_score/ AA_technical_anatomy_possible;
Expert discriminators	AA_expertdis_score= AA_Q8_expdis_score + AA_Q9_score + AA_Q10_score; AA_expertdis_possible= AA_Q8_expdis_possible + AA_Q9_possible + AA_Q10_possible;
AA technical (formerly T and TP combined)	AA_all_technical_score= AA_technical_anatomy_score+ AA_expertdis_score; AA_all_technical_possible= AA_technical_anatomy_possible +

	AA_expertdis_possible; AA_all_technical_percent= AA_all_technical_score/ AA_all_technical_possible;

Brachial Artery

Component name	Description
BA objective score	BA_objective_score= BA_Q1_mean_score + BA_Q2_mean_score + BA_Q3_mean_score + BA_Q4_mean_score + BA_Q5_mean_score + BA_Q6_score + BA_Q7_score + BA_Q7_expdis_score + BA_Q8_expdis_score + BA_Q10_mean_score + BA_Q11_mean_score;
BA possible objective score	BA_objective_score_possible= BA_Q1_possible_mean + BA_Q2_possible_mean + BA_Q3_possible_mean + BA_Q4_possible_mean + BA_Q5_possible_mean + BA_Q6_possible + BA_Q7_possible + BA_Q7_expdis_possible + BA_Q8_expdis_possible + BA_Q10_possible_mean + BA_Q11_possible_mean;
BA knowledge	/*knowledge: anatomy*/ BA_know_anatomy_score= BA_Q1_mean_score + BA_Q4_mean_score + BA_Q6_score + BA_Q7_score + BA_Q10_mean_score + BA_Q11_mean_score; BA_know_anatomy_possible= BA_Q1_possible_mean + BA_Q4_possible_mean + BA_Q6_possible + BA_Q7_possible + BA_Q10_possible_mean + BA_Q11_possible_mean; BA_know_anatomy_percent= BA_know_anatomy_score/ BA_know_anatomy_possible; /*knowledge: management*/ BA_know_manage_score= BA_Q2_mean_score + BA_Q5_mean_score;

	BA_know_manage_possible= BA_Q2_possible_mean + BA_Q5_possible_mean; BA_know_manage_percent= BA_know_manage_score/BA_know_manage_possible; /*knowledge: just*/ BA_know_general_score= BA_Q3_mean_score; BA_know_general_possible= BA_Q3_possible_mean; /*all knoweldge questions*/ BA_all_know_score= BA_know_anatomy_score + BA_know_manage_score + BA_know_general_score; BA_all_know_possible= BA_know_anatomy_possible + BA_know_manage_possible + BA_know_general_possible;
BA anatomy	BA_all_anatomy_score= BA_know_anatomy_score + BA_technical_anatomy_score; BA_all_anatomy_possible= BA_know_anatomy_possible + BA_technical_anatomy_possible; BA_all_anatomy_percent= BA_all_anatomy_score/ BA_all_anatomy_possible;
BA technical procedure scores	BA_technical_anatomy_score= BA_Q6_score + BA_Q7_score; BA_technical_anatomy_possible= BA_Q6_possible + BA_Q7_possible; BA_technical_anatomy_percent= BA_technical_anatomy_score/ BA_technical_anatomy_possible;
BA expert discriminators	BA_expertdis_score= BA_Q7_expdis_score + BA_Q8_expdis_score; BA_expertdis_possible= BA_Q7_expdis_possible + BA_Q8_expdis_possible;
BA all technical (formerly T and TP combined)	BA_all_technical_score= BA_technical_anatomy_score+ BA_expertdis_score; BA_all_technical_possible= BA_technical_anatomy_possible + BA_expertdis_possible; BA_all_technical_percent= BA_all_technical_score/

	BA_all_technical_possible;

Femoral Artery

Component name	Description
FA knowledge	FA_know_anatomy_score= FA_Q1_mean_score + FA_Q6_mean_score + FA_Q11_score + FA_Q12_mean_score; FA_know_anatomy_possible= FA_Q1_possible_mean + FA_Q6_possible_mean + FA_Q11_possible + FA_Q12_possible_mean; FA_know_percent= FA_know_anatomy_score/FA_know_anatomy_possible; FA_know_manage_score= FA_Q2_mean_score + FA_Q3_mean_score + FA_Q5_mean_score; FA_know_manage_possible= FA_Q2_possible_mean + FA_Q3_possible_mean + FA_Q5_possible_mean; FA_know_manage_percent= FA_know_manage_score/ FA_know_anatomy_possible; FA_know_general_score= FA_Q4_mean_score; FA_know_general_possible= FA_Q4_possible; FA_know_general_percent= FA_know_general_score/FA_know_general_possible; FA_all_know_score= FA_know_anatomy_score + FA_know_manage_score + FA_know_general_score; FA_all_know_possible= FA_know_anatomy_possible + FA_know_manage_possible + FA_know_general_possible;
FA Technical scores	FA_technical_anatomy_score= FA_Q7_score + FA_Q8_score; FA_technical_anatomy_possible= FA_Q7_possible + FA_Q8_possible; FA_technical_anatomy_percent= FA_technical_anatomy_score/FA_technical_anatomy_possible;
FA anatomy	FA_all_anatomy_score= FA_know_anatomy_score + FA_technical_anatomy_score; FA_all_anatomy_possible= FA_know_anatomy_possible +

	FA_technical_anatomy_possible; FA_all_anatomy_percent= FA_all_anatomy_score/ FA_all_anatomy_possible;
FA expert discriminators	FA_expertdis_score= FA_Q8_expdis_score + FA_Q9_expdis_score; FA_expertdis_possible= FA_Q8_expdis_possible + FA_Q9_expdis_possible; FA_expertdis_percent= FA_expertdis_score/ FA_expertdis_possible;
FA all technical (formerly T and TP)	FA_all_technical_score= FA_technical_anatomy_score+ FA_expertdis_score; FA_all_technical_possible= FA_technical_anatomy_possible + FA_expertdis_possible; FA_all_technical_percent= FA_all_technical_score/ FA_all_technical_possible;
FA objective score (combination of correct responses and errors)	FA_objective_score= FA_Q1_mean_score + FA_Q2_mean_score + FA_Q3_mean_score + FA_Q4_mean_score + FA_Q5_mean_score + FA_Q6_mean_score + FA_Q7_score + FA_Q8_score + FA_Q8_expdis_score + FA_Q9_expdis_score + FA_Q11_score + FA_Q12_mean_score; FA_objective_score_possible= FA_Q1_possible_mean + FA_Q2_possible_mean + FA_Q3_possible_mean + FA_Q4_possible_mean + FA_Q5_possible_mean + FA_Q6_possible_mean + FA_Q7_possible + FA_Q8_possible + FA_Q8_expdis_possible+ FA_Q9_expdis_possible+ FA_Q11_possible + FA_Q12_possible_mean;

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.**

- **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.**

Q1: Question #1. What are the structures you suspect could be injured along the path of the bullet?

Expected Answers checklist:

S1: The participant described each of the following as potentially injured:		
	Yes	**No**
A1: Axillary Artery		
Axillary Vein		
Brachial Plexus		
Lung		
Subclavian Artery		
Subclavian Vein		
Mediastinal structures		
A8: Bones		

Q2: Question #2. What physical findings will you look for to help you decide which structures are injured? Include signs of vascular, thoracic, nerve, and bone injury.

Expected Answers checklist:

S1: The participant describes each of the following physical findings and tests:		
	Yes	**No**
A1: Decreased breath sounds		
Active arterial bleeding		
Enlarging or expanding Hematoma		
Absent distal pulses		
Distal Ischemia		
Bruit or palpable thrill		
- Indicates that any or all of above are "hard signs" of vascular injury		
Active venous bleeding		
Unequal blood pressure, decreased Brachial-Brachial Index		
Doppler pulses—diminished flow		
Sensory loss		
Loss of motor function – weakness, inability to move arm		
Bony instability, deformation, crepitus		
Sub-cutaneous air		
A15: Tracheal deviation		

The patient's blood pressure is 85/65 and HR 110 and is unable to move his arm, has decreased sensation and absent brachial, radial, and ulnar pulses.

Q3: Question #3:

What additional studies would you perform to help you identify or rule out specific injuries in this patient?

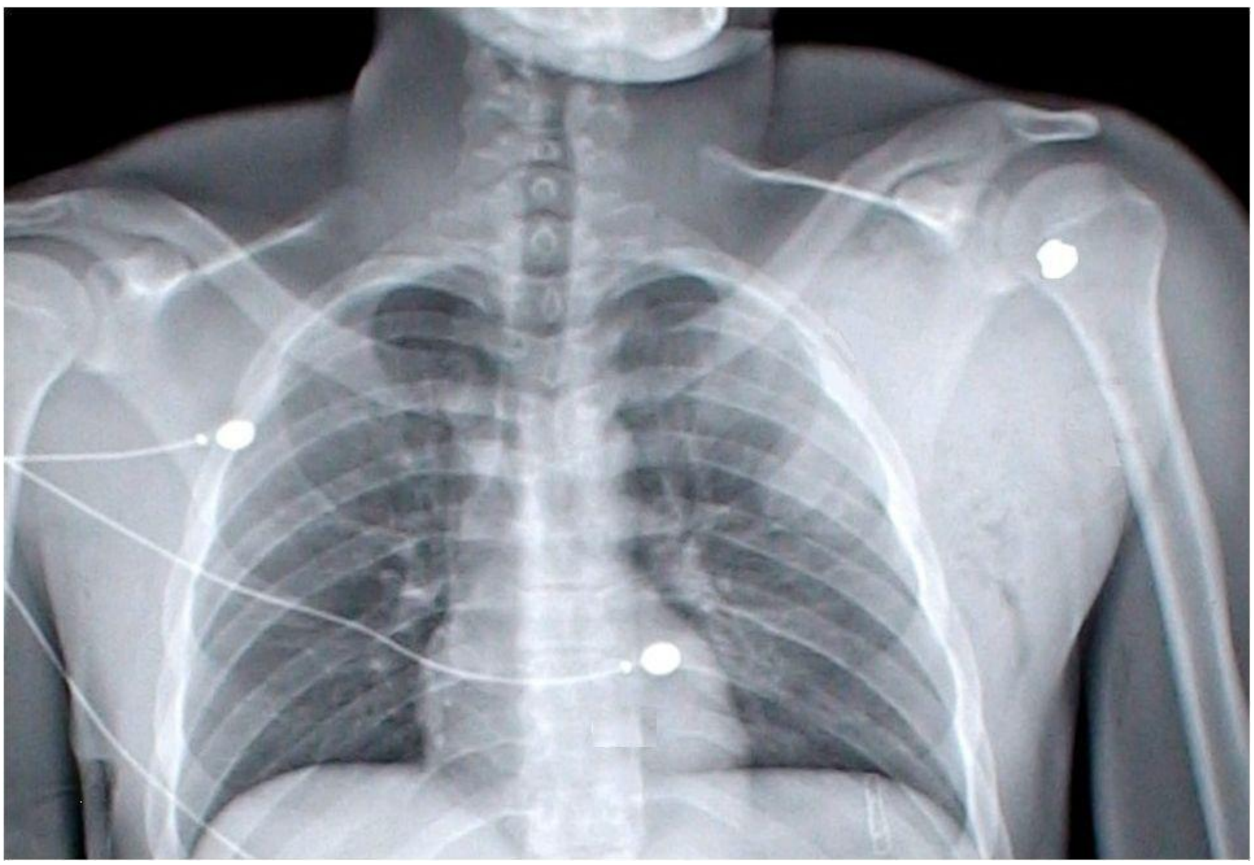
Expected Answers checklist:

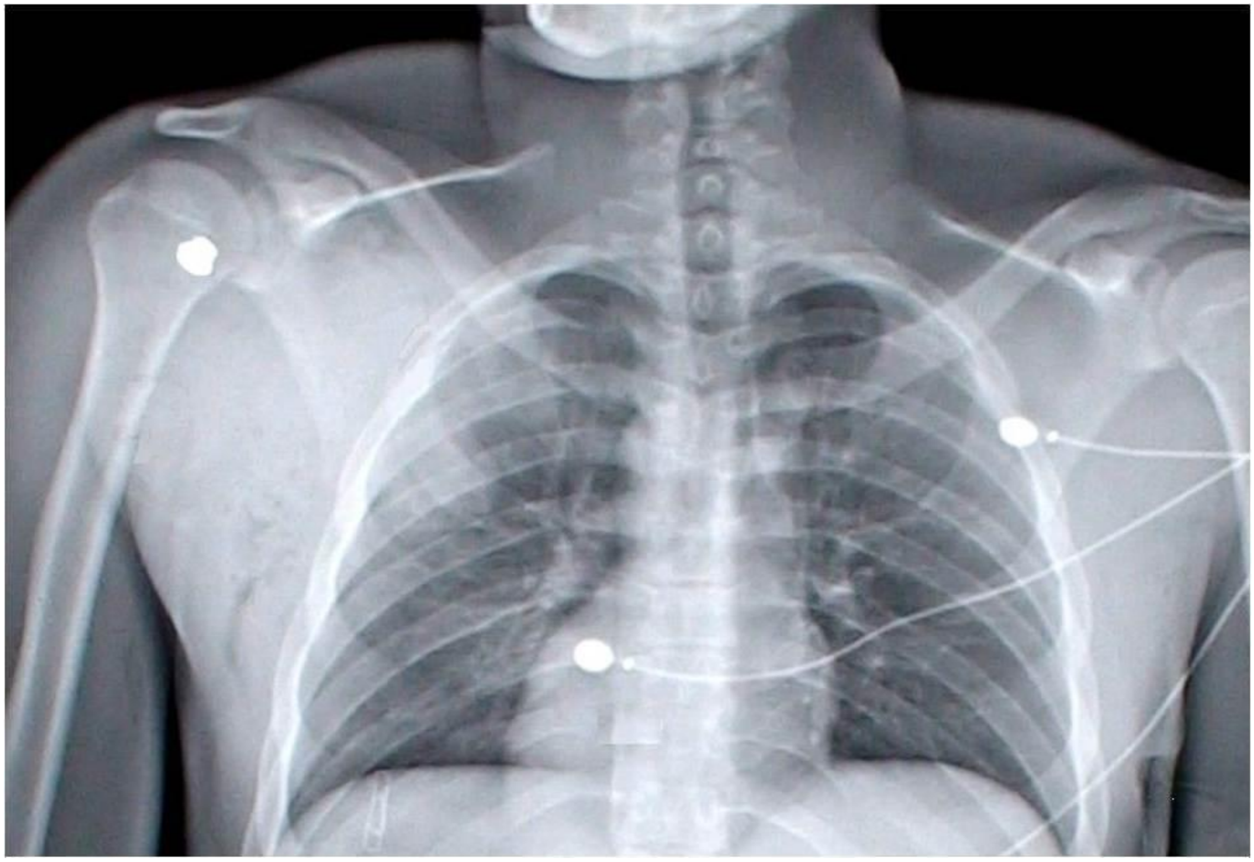
S1: The participant described each of the following as additional studies		
	Yes	**No**
A1: FAST exam to look for pericardial tamponade, hemothorax, pneumothorax		
Chest X-ray		
A3: A marker (eg paperclip) is placed to mark wound prior to x-ray		
E1: Error: Fails to obtain CXR		
A4: CT of Chest (zero points)*		
CT Angiogram (zero pts)*		
A6: Angiogram (zero points)*		

E2: Error: Inappropriate use of CT or Angio*	

All of the above tests are acceptable possible studies but the participant should clearly indicate these tests <u>should only be done in a hemodynamically stable patient</u>. Without this qualifier, performing any of these tests prior to taking this patient to the OR has potential for negative outcome & should result in negative value scoring.

***Scoring Note: no additional points are added for additional studies**





A chest x-ray has been obtained and shows no evidence of hemo or pneumothorax. There is a bullet fragment adjacent to the mid-portion of the ipsilateral scapula just superficial to the skin of the back – In other words a bullet trajectory from front to back on the same side, which does NOT involve the thoracic cavity.

Now the BP is 89/69 HR is 110. There is no other obvious trauma and his hand is cool and pale.

Q4: Question #4:

Now that you have seen the wound, physical findings, and chest x-ray, what is your plan for this patient?

If the participant suggests a non-operative course – they should be informed that: **the patient is now in the operating room and needs exposure and control of the axillary artery.**

Expected Answers checklist:

S1: The participant states the following plan		
	Yes	**No**

A1: **Patient should be taken urgently to the Operating room**		
E1: **Error: Delay in going to the operating room**		

Q5: Question #5:

What is your plan to resuscitate this patient? Include fluids or medications you would use during the initial resuscitation.

Expected Answers checklist:

S1: The participant describes each of the following additional items the patient might receive:		
	Yes	**No**
A1: **Resuscitate with blood products**		
Transfuse with high ratio of blood:FFP:platelets/ Massive transfusion protocol		
Minimize crystalloid infusion		
Limit volume resuscitation until bleeding controlled		
Do not delay surgery for resuscitation, resuscitate in OR		
Give TXA		
A7: Large bore IV access		

The patient has now been transported to the Operating Room and is on the OR table in front of you.

Question OR # 1: (Q6)

How would you position and prep this patient in order to repair this injury and explain why you chose to prep as you did?

Expected Answers checklist:

S1: The participant Indicates the following in response:		
	Yes	**No**
A1: **The patient should be supine**		
A2: **The arm extended on an arm board**		

S2: The prep should include:		
A1: **The Entire Chest**		
States possible need for sternotomy for proximal control		
The Entire arm and hand on the affected side		
States need to evaluate perfusion to the hand		
The thigh/groin for possible vein harvest		
The neck		
States possible need to expose subclavian artery for proximal control		
S2E1: **Error: Fails to prep entire chest**		
S2E2: **Error: Fails to prep entire arm and hand.**		

S2E3: **Error: Fails to prep the thigh for vein harvest**	

Question OR # 2: Q7

At this time, please describe and then mark on the skin the landmarks and the incision that you plan to use.

Expected Answers checklist:

S1The participant Indicates the following in response:		
	Yes	**No**
S1A1**The sternal notch**		
The clavicle		
The deltopectoral groove		
S1A4:**Incision runs from mid-clavicle laterally in deltopectoral groove.**		

EXPOSURE OF AXILLARY ARTERY

"Now I would like you to get control of the Axillary Artery proximal to the wound by dissecting and placing a vessel loop around the artery. As you operate, speak out loud and identify each step of the procedure. It is not necessary to rush through the procedure—you should operate at a comfortable pace. The procedure will be deemed complete once you have placed a vessel loop around the axillary artery to obtain proximal control. Do you have any questions? If not please proceed."

Q8: **Expected operative dissection performance checklist:**

The participant describes and performs each of the following steps:			
	Yes	**No**	**Time**
S1A1: **Initial skin incision is adequate to perform exposure**			**Start Incision** Blank
Splitting or dividing Pectoralis Major			**Start Dissection** Blank
Divides Pectoralis Minor			
Correctly identifies Axillary Artery			
Correctly identifies Axillary Vein			
Correctly identifies brachial plexus			
S1A7: **Controls the Axillary Artery Proximal to injury**			**Finish** Blank
S1E1: **Error: Incorrectly identifies the Axillary artery and does not recognize or correct error**		Q8S1A7_time: *(indicates duration of procedure)*	
S1E2: Error: Incorrectly identifies the Axillary Artery but is able to recognize and correct			

***Q8S2:* Technique points**

	Score 1-5
Q8S2A1: Exposes arteries by dissecting directly on anterior surface†*	
Manipulates artery by grasping adventitia†*	
Uses instruments properly	
Positions body to use instruments to best advantage	
Proceeds at appropriate pace with economy of movement	
Handles tissue well with minimal damage	
Creates an adequate visual field using retractors for procedure	
Communicates clearly and consistently	
Performs procedure without unnecessary dissection	
Q8S2A10: Continually progresses towards the end goal	

(5) Every time/Excellent; (4) Almost every time/Very good; (3) Sometimes/Good; (2) Rarely/Fair; (1) Never/Poor

*N/A for model, †***Score (1) if participant never finds an artery***

Q9S1: Expert Discriminator Operative Field Maneuvers for Axillary Artery Exposure

	Yes	**No**
Q9S1A1: Operates through 'key-hole' or too small a skin incision	0	1
Operates using full incision	1	0
Excessive dissection	0	1
Pointless digging and shifting around in surgical field	0	1
Has a logical operating sequence	1	0
Q9S1A6: Lacks anatomical knowledge	0	1

Q10S2 : Expert Discriminatory Instrument Use for Axillary Artery Exposure

	Yes	**No**
Q10S1A1: Improper instrument use (e.g. back-handed use)	0	1
Incorrect instrument holding (e.g. forceps too near tips, thumb through scissors handle)	0	1
Scalpel use: multiple tentative cuts or cuts tangentially	0	1
Switches instruments excessively	0	1
Effective use of blunt dissection	1	0
Dedicated use of a single instrument.	0	1
Q10S1A7: Uses sharp dissection (knife or scissors) confidently	1	0

Questions in OR, after dissection:

Q11S1: What are the consequences of ligating the axillary artery?

The participant answered the questions correctly:		
	Yes	**No**
A1: Ligation of the axillary generally does not cause ischemia due to extensive collaterals around the shoulder.		

Q12S1: What are the pitfalls or common errors that one might expect with this procedure?

Possible Answers		
	Yes	**No**
A1: Incision – too high, too low, wrong location		
Iatrogenic injury to nerve, artery, vein		
Inability to get proximal control – needing to go above clavicle or into chest		
Diving into clot or hematoma without adequate control		
A5: Mistaking nerve for artery		

AXILLARY ARTERY EXPOSURE GLOBAL RATING (circle one)**:**

G1: Overall Understanding of the Evaluation and Treatment of a Patient with a Suspected Axillary Artery Injury:

1	2	3	4	5
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.

G2: Overall Understanding of the Surgical Anatomy of the Axillary Region:

1	2	3	4	5
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.

G3: Technical Skills for Exposing the Axillary Artery:

1	2	3	4	5
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.

G4: This participant is ready to perform exposure and control the Axillary Artery:

1	2	3	4	5
The patient has exsanguinated. Participant is not ready to perform the exposure.	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.

ER: Evaluator's overall rating (1-100) ______________________________

≥ 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 The patient has exsanguinated. Participant is not ready to perform the exposure.

The overall score should be the instructor's subjective rating of how well the surgeon performed. This will be compared to the objective score for the purpose of validating the scoring method.

BH: Body Habitus of cadaver (Circle):

Obese Average Thin

CA: Cadaver Anatomy (Circe):

Normal Variant

Name of Evaluator: **Date:**

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

1st Trial

Circle type of trial: Cadaver / Model

Case Two: Brachial Artery

Case Presentation

- **32 y/o male was accidentally shot in the arm at close range with a hunting rifle.**
- **He was reported to have had large pulsatile blood loss at the scene.**

Case two- Left

Entrance wound L dorsal forearm

Exit wound medial upper arm

Case two- Right

Entrance wound R dorsal forearm

Exit wound medial upper arm

- **There is active pulsatile bleeding from the medial wound which is currently being controlled with direct pressure by the paramedic.**
- **Distal pulses are absent.**
- **BP = 100/68, HR = 120**
- **There are no other injuries.**

Q1: Question #1:

What are the structures you suspect could be injured, including nerve, artery, vein, or other?

Expected Answers checklist:

S1: The participant described each of the following as potentially injured:		
	Yes	**No**
A1:**Brachial Artery**		
Median Nerve		
Radial Nerve		
Humerus		
Radius, Ulna		
A6: Veins		

BP is 105/70 and HR is 110. The patient has no neurologic deficit, but has absent radial and ulnar pulses.

Q2:Question #2:

What additional studies would you perform to help you identify or rule out specific injuries in this patient?

Expected Answers checklist:

The participant described each of the following as additional studies		
	Yes	**No**
A1: **X-ray of arm**		
Chest X-ray		
CT Angiogram (zero pts)		
A4: Angiogram (zero points)		
E1: **Error: Inappropriate use of CT or Angio***		

All of the above tests are acceptable possible studies but the participant should clearly indicate these tests <u>should only be done in a hemodynamically stable patient</u>. Without this qualifier, performing any of these tests prior to taking this patient to the OR has potential for negative outcome & should result in negative value scoring.

***Scoring Note: no additional points are added for additional studies**

Arm X-ray shows no fracture and no retained fragments. Chest X-ray is normal (if ordered).

Q3: Question #3:

What is your plan for this patient?

If the participant persists in suggesting a non-operative course – they should be informed that **"the patient is now in the operating room."**

Expected Answers checklist:

S1: The participant states the following plan		
	Yes	**No**
A1: Patient should be taken urgently to the Operating room		
E1: Error: Delay in going to the operating room		

The Patient has now been transported to the Operating Room and is on the OR table in front of you.

Q4: Question OR # 1:

How would you position and prep this patient in order to repair this injury and explain why you chose to prep as you did?

Expected Answers checklist:

S1: The participant Indicates the following in response:		
	Yes	**No**
A1: The patient should be supine		
The arm extended on an arm board		

S2: The prep should include:		
A1: The entire arm and hand on the affected side		
Mentions need to evaluate perfusion to the hand		
The Axilla on the affected side		
Mentions possible need to expose axillary artery for proximal control		
A5: The thigh/groin for possible vein harvest		
E1: Error: Fails to prep entire arm and hand.		
E2: Error: Fails to prep the thigh for vein harvest		

Q5: Question OR # 2:

Can you describe how you plan to gain control of the bleeding vessel using general principles of vascular surgery?

Expected Answers checklist:

S1: The participant indicates the following principles of vascular exposure:		
	Yes	**No**
A1: Proximal control first		
Distal control second		
A3: Expose injury		

Q6: Question OR # 3:

At this time, please describe and then mark on the skin the landmarks and the incision that you plan to use.

Expected Answers checklist:

S1: The participant Indicates and marks the following landmarks:		
	Yes	**No**
A1: The biceps and triceps		
The humerus		
A3: Incision between biceps and triceps bellies		

<u>EXPOSURE OF BRACHIAL ARTERY</u>

"Now I would like you to surgically expose and control the Brachial Artery with a vessel loop in order to gain proximal control. As you operate, <u>speak out loud</u> and identify each step of the procedure. It is not necessary to rush through the procedure. The procedure will be deemed complete once you have placed a vessel loop around the Brachial artery to obtain proximal control. Do you have any questions? If not please proceed"

Q7: Expected operative dissection performance checklist:

S1: The participant describes and performs each of the following steps:			
	Yes	**No**	**Time**
A1: Initial skin incision is adequate to perform exposure			**Start Incision** **Blank**
Creates a plane of dissection between the Biceps and Triceps			**Start Dissection** **Blank**
Correctly identifies Median Nerve			
Retracts and protects Median Nerve			
Correctly identifies Brachial Artery			
Dissects Brachial Artery away from venae comites			
A7: Controls Brachial artery with vessel loop proximal to the injury			**Finish** **Blank**
E1: Error: Incorrectly identifies the Brachial Artery and does not recognize or correct error		**Q7S1A7_time**	
Error: Incorrectly identifies the Brachial Artery but is able to recognize and correct			

Q7S2: *Technique points*

	Score 1-5
A1: Exposes arteries by dissecting directly on anterior surface†*	
Manipulates artery by grasping adventitia†*	
Uses instruments properly	
Positions body to use instruments to best advantage	
Proceeds at appropriate pace with economy of movement	
Handles tissue well with minimal damage	
Creates an adequate visual field using retractors for procedure	
Communicates clearly and consistently	
Performs procedure without unnecessary dissection	
A10: Continually progresses towards the end goal	

(5) Every time/Excellent; (4) Almost every time/Very good; (3) Sometimes/Good; (2) Rarely/Fair; (1) Never/Poor

*N/A for model, †***Score (1) if participant never finds an artery***

Q8S1: Expert Discriminator Operative Field Maneuvers for Brachial Artery Exposure

	Yes	**No**
A1: Operates through 'key-hole' or too small a skin incision		
Operates using full incision		
Excessive dissection		
Pointless digging and shifting around in surgical field		
Has a logical operating sequence		
A6: Lacks anatomical knowledge		

Q8S2: Expert Discriminatory Instrument Use for Brachial Artery Exposure

	Yes	**No**
A1: Improper instrument use (e.g. back-handed use)		
Incorrect instrument holding (e.g. forceps too near tips, thumb through scissors handle)		
Scalpel use: multiple tentative cuts or cuts tangentially		
Switches instruments excessively		
Excessive use of blunt dissection		
Dedicated use of a single instrument.		
A7: Uses sharp dissection (knife or scissors) confidently		

Questions in OR, after dissection:

Q10: What are the consequences of ligating the brachial artery?

S1: The participant answered the questions correctly:		
	Yes	No
A1: Can ligate the brachial artery: ligation above the profunda results in limb loss in 50% of cases; below the profunda results in limb loss in 5% of cases		

Q11: What are the pitfalls or common errors that one might expect with this procedure?

S1: Possible Answers		
	Yes	No
A1: Incision – too anterior, too posterior, wrong location		
Mistaking nerve for artery		
Iatrogenic injury to nerve, artery, vein		
A4: Diving into clot or hematoma at the injury site without adequate control		

BRACHIAL ARTERY EXPOSURE GLOBAL RATING (circle one):

G1: Overall Understanding of the Evaluation and Treatment of a Patient with a Patient with a suspected Brachial Artery Injury:

1	2	3	4	5
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.

G2: Overall Understanding of the Surgical Anatomy of the Arm:

1	2	3	4	5
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.

G3: Technical Skills for Exposing the Brachial Artery:

1	2	3	4	5
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.

G4: This Participant is Ready to Perform Exposure and Control of the Brachial Artery and its Branches:

1	2	3	4	5
The patient has exsanguinated. Participant is not ready to perform the exposure.	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.

ER: Evaluator's overall rating (1-100) ______________________

≥ 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 The patient has exsanguinated. Participant is not ready to perform the exposure.

The overall score should be the instructor's subjective rating of how well the surgeon performed. This will be compared to the objective score for the purpose of validating the scoring method.

BH Body Habitus of cadaver (Circle):

Obese Average Thin

CA Cadaver Anatomy (Circe):

Normal Variant

Name of Evaluator: **Date:**

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

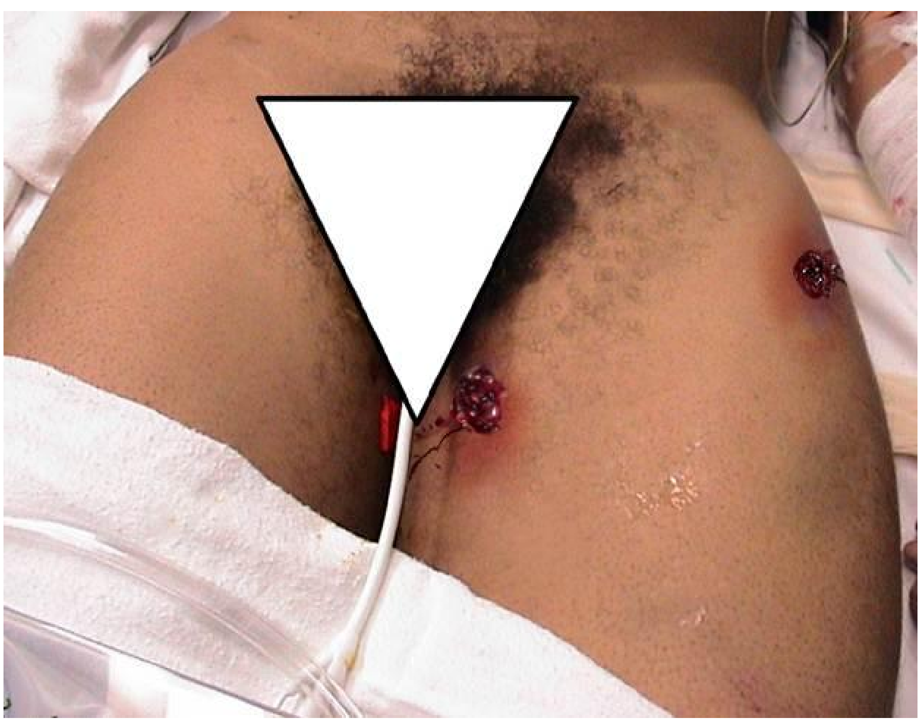
1st Trial

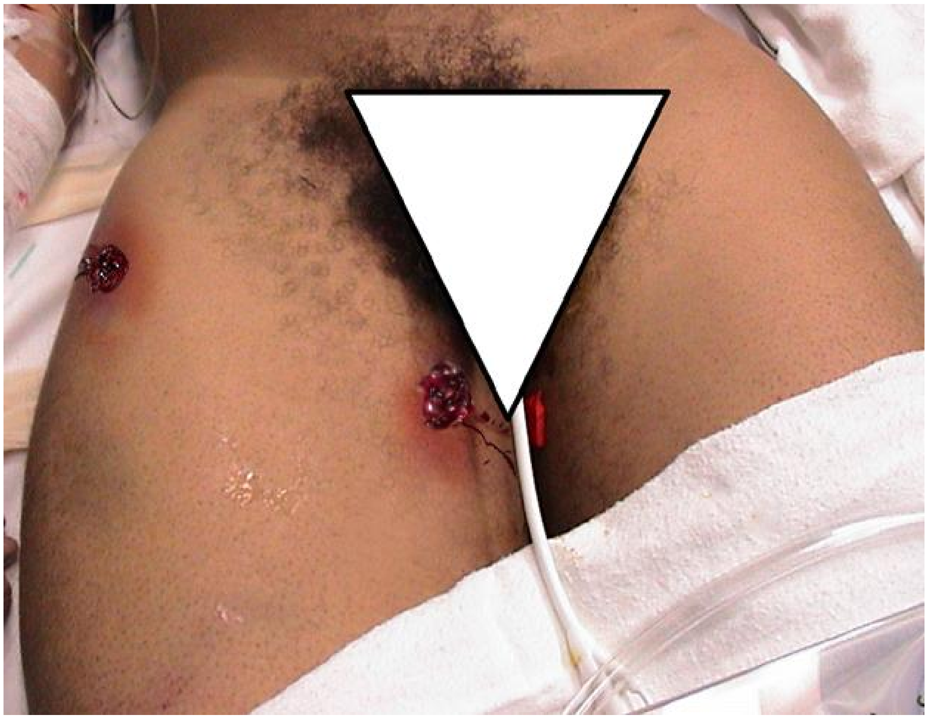
Circle type of trial: Cadaver / Model

Case Three: Femoral Artery

Case History:

- **24 y/o male who was a victim of a drive by shooting, sustaining a through and through gunshot wound to the Right/Left mid-thigh**
- **He was reported to have a large amount of bright red pulsatile blood at the scene**
- **He was initially taken to a small community hospital without an in-house surgeon where his blood pressure was 80/50 and his heart rate was 140. He was reported to have a markedly swollen thigh with active bleeding and no distal pulses. There are no other injuries.**





- **At the outside hospital a tourniquet was placed and he received 3000 cc of crystalloid. He is transferred to your facility now more than four hours after the injury. He received low dose norepinephrine and has a blood pressure of 100/70 and a HR of 130, with a markedly swollen thigh and absent distal pulses.**

Q1: Question #1:

What are all the structures you suspect <u>could</u> be injured, including nerve, artery, vein, or other structure?

Expected Answers checklist:

S1: The participant described each of the following as potentially injured:		
	Yes	**No**
A1: **Common Femoral Artery**		
Common Femoral Vein		
Superficial Femoral Artery		
Superficial Femoral Vein		
Femoral Nerve/Branches		
Profunda Femoral Artery		
A7: Femur		

Q2: Question #2:

What are the physical findings that may help you determine which structures are injured in this patient, including signs of vascular, nerve, and bone injury?

Expected Answers checklist:

S1: The participant describes each of the following physical findings and tests:		
	Yes	**No**
A1: Loss of Popliteal/DP/PT pulses		
Pulsatile bleeding		
Expanding hematoma		
Hemorrhagic shock		
Unstable femur or crepitance of bone		
Ankle-Ankle or Ankle-Brachial Index		
Neurologic deficits in femoral nerve distribution:		
Sensation to anterior thigh		
A8: Motor to hip flexion, knee extension		

BP is 95/65 and HR is 125. The patient has a cool and pulseless foot, he is able to move the ankle and foot, but is unable to extend the knee. There is numbness on the anterior thigh.

Q3: Question #3:

What additional studies would you perform to help you identify or rule out specific injuries in this patient?

Expected Answers checklist:

S1: The participant described each of the following as additional studies		
	Yes	**No**
A1: X-ray of femur		
Chest X-ray (zero points)*		
CT Angiogram (zero pts)*		
A4: Angiogram (zero points)*		
E1: Error: Inappropriate use of CT or Angio*		

All of the above tests are acceptable possible studies but the participant should clearly indicate these tests <u>should only be done in a hemodynamically stable patient</u>. Without this qualifier, performing any

of these tests prior to taking this patient to the OR has potential for negative outcome & should result in negative value scoring.

***Scoring Note: no additional points are added for additional studies**

The femoral X-ray shows no fracture and no retained fragments. Chest X-ray is normal (if obtained).

*****If Sup Femoral artery injury has not been recognize—Tell the participant explicitly that the patient has an injury to the Superficial Femoral Artery.***

Q4: Question #4:
What is your plan for this patient?

FYI: If the participant persists in suggesting a non-operative course – **Inform the participant that the patient is now in the operating room and needs exposure and control of the Femoral Artery.**

Expected Answers checklist:

S1: The participant states the following plan		
	Yes	**No**
A1: Patient should be taken urgently to the Operating room		
E1: Error: Delay in going to the operating room		

Q5: Question #5:

What interventions are important to resuscitate and treat this patient before and during surgery?

Question #5.5:

Are there any systemic consequences of delayed diagnosis?

Question #6:

What further management would you consider given the ischemic time which is already greater than 4 hours?

Expected Answers checklist:

The participant describes each of the following additional items the patient might receive:		
	Yes	**No**

S1 A1 **Resuscitate with blood products**		
Transfuse with high ratio of blood:FFP:platelets/ Massive transfusion protocol		
Wean off norepinephrine		
Minimize crystalloid		
A5 Give TXA		

S2 A1 Volume load		
Bicarbonate		
A6Monitor for arrhythmia		
Monitor for rhabdomyolysis		
Temporary vascular shunt		
A6 **Recognize need for fasciotomy**		

The patient has now been transported to the Operating Room and is on the OR table in front of you.

Q6: Question OR # 1:

How would you position and prep this patient in order to repair this injury and explain why you chose to prep as you did?

Expected Answers checklist:

S1: The participant Indicates the following in response:

	Yes	No
A1: The patient should be supine		
Leg externally rotated and knee supported		

S2: The prep should include:		
A1: The entire lower extremity, including foot on the affected side		
States need to assess perfusion to the foot		
States possible need for fasciotomy		
A4: The thigh/groin on the contralateral side for possible vein harvest		
E1: Error: Fails to prep entire lower extremity, including foot on effected side		
Error: Fails to prep the contralateral groin		

Q7: Question OR # 2:

At this time, please verbalize and then mark on the cadaver the landmarks and the incision that you will use on the skin.

Expected Answers checklist:

S1: The participant Indicates and marks the following landmarks		
	Yes	**No**
A1: Pubic tubercle		
Ant Sup iliac Spine (ASIS)		
Inguinal ligament		
Femoral artery (approximate location 1/3 of distance from pubic tubercle to ASIS)		
Marks longitudinal incision over femoral artery, 2 finger breadths lateral to the pubic tubercle		
A6: Incision extends above inguinal ligament 4-5 cm		

EXPOSURE OF FEMORAL ARTERY

"At this time, I would like you to surgically explore and control the Common Femoral Artery, the Superficial Femoral Artery, and Profunda Femoral Artery. As you operate, speak out loud and identify each step of the procedure. It is not necessary to rush through the procedure. The procedure will be deemed complete once you have placed a double vessel loop around the Common Femoral, Superficial Femoral, and Profunda Femoral arteries to obtain proximal control. Do you have any questions? If not please proceed."

Q8: Expected operative dissection performance checklist:

S1: The participant describes and performs each of the following steps:			
	Yes	**No**	**Time**
A1: Initial skin incision is adequate to perform exposure			**Start Incision**
Correctly identifies Common Femoral Artery			**Start Dissection**
Correctly identifies Common Femoral Vein			
Correctly identifies Profunda Femoral Branch			
Correctly identifies Superficial Femoral Artery			
Controls Common Femoral Artery with vessel loop			
Controls Profunda Femoral Artery with vessel loop			
A8: Controls Superficial Femoral Artery with vessel loop			**Finish**
Error: Incorrectly identifies the E1 CFA, E3 SFA, or E5 PFA and does not recognize or correct error		**Q8S1A8_time**	
Error: Incorrectly identifies E2 CFA, E4 SFA, or E6 PFA, but is able to recognize and correct			

Q8S2: Technique points

	Score 1-5
A1: Exposes arteries by dissecting directly on anterior surface†*	
Manipulates artery by grasping adventitia†*	
Uses instruments properly	
Positions body to use instruments to best advantage	
Proceeds at appropriate pace with economy of movement	
Handles tissue well with minimal damage	
Creates an adequate visual field using retractors for procedure	
Communicates clearly and consistently	
Performs procedure without unnecessary dissection	
A10: Continually progresses towards the end goal	

(5) Every time/Excellent; (4) Almost every time/Very good; (3) Sometimes/Good; (2) Rarely/Fair; (1) Never/Poor

*N/A for model, †***Score (1) if participant never finds an artery***

Q9S1: Expert Discriminator Operative Field Maneuvers for Femoral Artery Exposure

	Yes	**No**

A1 Operates through 'key-hole' or too small a skin incision		
Operates using full incision		
Excessive dissection		
Pointless digging and shifting around in surgical field		
Has a logical operating sequence		
A6: Lacks anatomical knowledge		

Q9S2: Expert Discriminatory Instrument Use for Femoral Artery Exposure

	Yes	**No**
A1: Improper instrument use (e.g. back-handed use)		
Incorrect instrument holding (e.g. forceps too near tips, thumb through scissors handle)		
Scalpel use: multiple tentative cuts or cuts tangentially		
Switches instruments excessively		
Effective use of blunt dissection		
Dedicated use of a single instrument.		
A7: Uses sharp dissection (knife or scissors) confidently		

Questions in OR, after dissection:

Q11: What are the consequences of ligating the Superficial Femoral artery? What are the consequences of ligating the Superficial Femoral vein?

S1: The participant answered the questions correctly:		
	Yes	**No**
A1: SFA results in severe limb ischemia /requires amputation		
SFV ligation may cause limb edema		

Q12: What are the pitfalls or common errors that one might expect with this procedure?

S1: Possible Answers		
	Yes	**No**
A1: Incision – too high, too low, wrong location		
Iatrogenic injury to nerve, artery, vein		
Inability to get proximal control below the inguinal ligament		
Diving into clot or hematoma at the injury site without adequate proximal and distal control		
Mistaking nerve for artery		
A6: Variable location of Profunda Femoral Artery or mistaking SFA for CFA		

FEMORAL ARTERY EXPOSURE GLOBAL RATING (circle one):

G1: Overall Understanding of the Evaluation and Treatment of a Patient with a Suspected Superficial Femoral Artery Injury:

1	2	3	4	5
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.

G2: Overall Understanding of the Surgical Anatomy of the Inguinal Region:

1	2	3	4	5
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.

G3:Technical Skills for Exposing Common Femoral Artery and Branches:

1	2	3	4	5
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.

G4 This Participant is ready to Perform Exposure and Control the Common Femoral Artery and Branches:

1	2	3	4	5
The patient has exsanguinated. Participant is not ready to perform the exposure.	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.

ER Evaluator's overall rating (1-100) ______________________________

≥ 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 The patient has exsanguinated. Participant is not ready to perform the exposure.

The overall score should be the instructor's subjective rating of how well the surgeon performed. This will be compared to the objective score for the purpose of validating the scoring method.

BH Body Habitus of cadaver (Circle):

Obese Average Thin

CA Cadaver Anatomy (Circe):

Normal Variant

Name of Evaluator: Date:

Flow Diagram of Study

When?	Who?	What?	Measurements used and data generated
Phase 1: Year 1 **Develop and validate surgical performance measures** • Technical skills performance metrics • Non-technical skills performance metrics • Mobile software to evaluate competency in technical and non-technical performance skills • Validate performance metrics with inter-rater reliability in preliminary studies	10 experts (fellowship trained, 2-40 years practice) 10 Non-ASSET trained novices (year 4-7 surgical residents and fellows) → N1 Novice grp 1	**Developing metrics** • Four procedures representative of vascular exposure for trauma from consult with expert surgeons • Video record of 10 Experts "Talk Aloud" during four ASSET procedures (AA, BA, FA and FAS) in fresh cadavers • Consensus Conference (discussion) among experts: identify essential expertise, common errors and correct technical Skills = Evaluation Metrics. **Testing metrics** • Video Record 10 Non-ASSET trained novices "Talk Aloud" during four ASSET procedures (AA, BA, FA and FAS) in fresh cadavers • Develop Standard Script: Train Evaluators: Incorporate Script and Evaluation Metrics into Mobile Tablet for 'real-time' evaluations and data collection. • Validate: Randomly ordered expert and Novice videos evaluated by trained video reviewers (n=5) blinded to E or N clips compared by item analysis. Note: only cadavers were used in phase 1	Note: There is no data on phase 1 experts. Any data on experts is for expert study participants→ called Expert 200 Series Phase 1 produced metrics to use on evaluating next phase surgeons. These metrics had objective and subjective components. **Individual procedure scores** (IPS) calculated for each of the four ASSET procedures (AA, BA, FA and FAS). Must use cadaver technical scores only to calculate IPS. **Objective measures →Trauma Readiness Index** (TRI) Metric =Index of Points Awarded / Points Possible for: 1. Procedural skills: 10 surgical steps 2. completion time (time remaining in allotted 20 minute window) 3. Knowledge – overall – knowledge of anatomy: diagnostic indications – management knowledge: patient management and decision making strategies 4. Technique points: operative maneuvers and tissue handing common to experts **Subjective Measures →** Evaluators also awarded 5 Global performance ratings & and overall performance "grade" (%). For this measure, evaluators could consider how confident participant surgeon was etc. Descriptive regression modeling. Intra-class correlation coefficient (ICC) for Inter-Rater Reliability. Technical skills metrics with ICC >0.7 included in subsequent before and after ASSET training TRI evaluations (technical skills 5,7,8 and 9 met this criteria) Note: Phase 1 Novices used a slightly different Instrument. It was also done on paper (prior to tablet usage) → missing data.
Phase 2:Years 2-3 Testing impact & skills retention (physical model & unpreserved cadavers)	40 Non-ASSET trained novices (year 4-7 surgical residents and fellows) → N2 Novice group #2	**Novices grp 2→ N2** • Evaluations of N2 done Pre (using cadavers) and 2 weeks Post ASSET training (using cadavers and models) → improvement due to training	• Surgical performance Novices vs. Experts using developed metrics • Demonstrate Evaluation of Objective and Subjective instructor assessments • Test performance metrics Pre and Post-training. Compare with self-

	10 experts (fellowship trained, 2-40 years practice) →Expert 200 Series	• Follow-up evaluation of N2 done 18 months Post ASSET training→ retention of training
		Note: At the Post visit (2 weeks), N2 surgeons performed 4 ASSET procedures on physical models and cadaver→ assessing model vs. cadaver to establish model appropriateness
		  • Cadaver and model used in randomized order.
		  • Each surgeon worked on BOTH one after the other
		  • Whichever was chosen 1st –full script used
		  • Whichever was chosen 2nd – abridge script (did not have repeats of knowledge questions)
		• Evaluations done by two evaluators: one surgeon (senior) and one non-surgeon (junior)
		• Maximum of 20 minutes allowed for completion of the four procedures (Note: this time limit was not always implemented)
		• N2 also performed self-evaluations of confidence/ perceived surgical skill four times (before and after their Pre-ASSET training evaluations, and before and after their Post-ASSET training evaluations)
		
		Experts 200
		• E200 only had <u>one visit</u>. They only got evaluated once Post-ASSET training using cadavers only and full script.
		• E200 also performed two self-evaluations of confidence/ perceived surgical skill (before and after their evaluations)
			assessments
			• Define time frames for deterioration of surgical skills
			• Assessing model vs. cadaver
			
			Note: Even though E200 were ‘experts’ based on their career stage. This expertise was not evaluated before they were evaluated. The “experts” were not necessarily ASSET trained (n=2 have never had ASSET training. Dropping these two from analysis has been discussed prior)
			
			Note: Pre-assessment of N2 used cadavers only
			Post-assessment of N2 used cadavers and model
			Follow-up (Also called retention) of N2 used cadavers only
			
			Note: the N2 follow-up visit also added the carotid artery evaluation on cadaver. Making 5 procedures rather than just 4. This data is found in a separate data file.

Phase 3:Years 2-3
 	
Performance evaluation metrics 1- 5 years after taking ASSET Course
 	
Examine various aspects of skills degradation over time, including comparison of skills degradation.
	40 previously ASSET trained surgeons (2-5 years from original training) → N3 Novice group #3
	
	Note: there was deliberate effort made to enroll surgeons who did not previously participate in the study. That is, N3≠ N2
		Note: N3 surgeons performed 4 ASSET procedures on physical models and cadaver→ assessing model vs. cadaver to establish model appropriateness
		• Cadavers and model used in randomized order.
		• Each surgeon worked on BOTH one after the other
		• Whichever was chosen 1st –full script used
		• Whichever was chosen 2nd – abridge script (did not have repeats of knowledge questions)
		
		• Assessments done using
		  ○ original performance assessment instruments
		  ○ newly-modified instruments
		  ○ TRR to assess degrees of
			• Surgical performance Novices (N3) using developed metrics
			• Demonstrate Evaluation of Objective and Subjective instructor assessments
			• Test performance metrics on retention. Compare with self-assessments
			• Define time frames for deterioration of surgical skills
			• Assessing model vs. cadaver
			
			Note: ‘SOME” of the N3 visit also added the carotid artery evaluation on cadaver. Making 5 procedures rather than just 4. This data is found in a separate data file.

		and factors affecting performance decay • Performance data will be compared using standard statistics. • Intra-class correlation coefficient will assess inter-rater reliability to validate modified TRR assessment of surgical performance.	

RASP PROCEDURE VIDEO INDEX

Axillary Artery Videos

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Lower Extremity Fasciotomy Videos

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Carotid Artery Videos

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RASP Evaluator Training Handbook

December 2013

Introduction

This handbook will serve as a guide and reference for evaluating a subset of surgical procedures taught in the Advanced Surgical Skills for Exposure in Trauma Course (ASSET) as part of the corresponding Retention and Assessment of Surgical Performance Project (RASP). You will view four ASSET procedures either in person or on video in order to score the individual participants performance on the score sheet provided. The purpose of this evaluation is for you to use your professional expertise to gauge the surgical technical skill level of each participant in gaining vascular control of the axillary, brachial, and femoral arteries and decompression of the 4 compartments around the tibia and fibula.

The first section of this handbook will contain the ASSET Faculty Manual Direction for each RASP procedure which you will use as your guide to determine the appropriate surgical approach. Four surgeries will be evaluated including: 1) axillary artery exposure; 2) brachial artery exposure; 3) femoral artery exposure; and, 4) lower extremity fasciotomy. The second section of this handbook includes the Evaluation sheets for the respective procedures, as well as, instructions describing how to fill them out. The Dictionary of Definitions spells out the terms used in the evaluations of surgical technical skills.

RASP Evaluation Process.

1) The RASP study candidate will be read a standard script (the same for all candidates whether they are in Phase 2 or 3 of the RASP study) before the start of each of the 4 RASP Procedures.
2) The script will describe a case scenario and provide instructions about what surgical approach is required (e.g. expose and gain proximal vascular control of the Femoral Artery, including the CFA, SFA and Profunda).
3) The RASP study candidate will be given the chance to ask questions, and then asked to proceed.

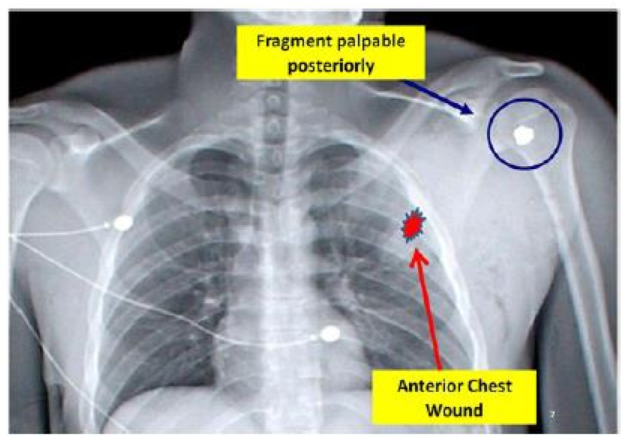
RASP Evaluator Role

1) The Evaluator should not ask the candidate questions
2) The evaluator should observe closely and record these surgical technique observations on the evaluation sheet , either electronically, or with pencil and paper
3) No prompting is allowed. No suggestions or teaching are allowed. Details of the case history may be repeated and the information may be displayed on the screen alongside the RASP study candidate.
4) The order of RASP procedures may vary. You and the RASP study candidates will be advised the Order in which the 4 RASP procedures will occur.

Section I: RASP Procedures (Taken from the ASSET instructor Handbook)

RASP Case One: Vascular Exposure of the Axillary Vessels

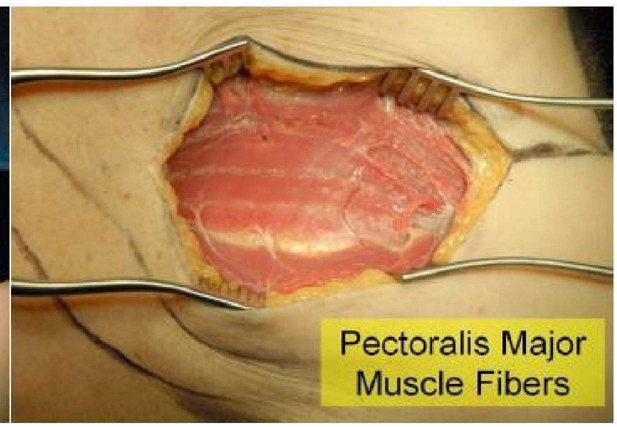
- 24 y/o male who was riding his bicycle to Sunday school "on a Friday night" attacked by two dudes and sustained GSW to the left upper chest
- Reported to have large amount of bright red pulsatile blood at scene
- On arrival awake and talking
- BS =Bilaterally B/P 96/60, HR = 126
- c/o pain at site of wound
- Unable to move left arm with decreased sensation
- Entrance wound only with large hematoma
- Brachial, radial and ulnar pulses absent hand cool and pale



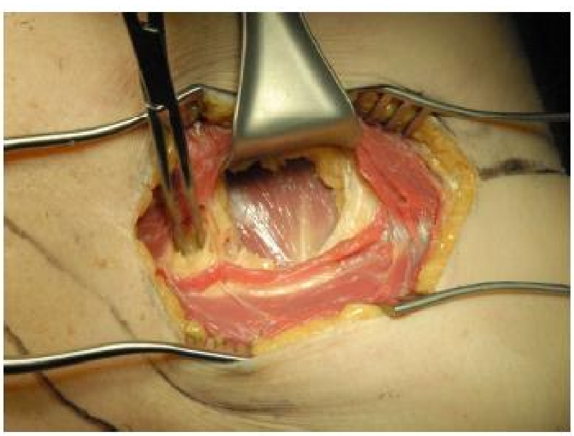
Teaching Objectives/Steps:

1. Anatomy
a. Subclavian becomes axillary as it crosses the first rib
b. The artery is divided into 3 sections by the pectoralis minor muscle
c. The brachial plexus is intimately associated with the artery and care must be taken to avoid injury during rapid exposure

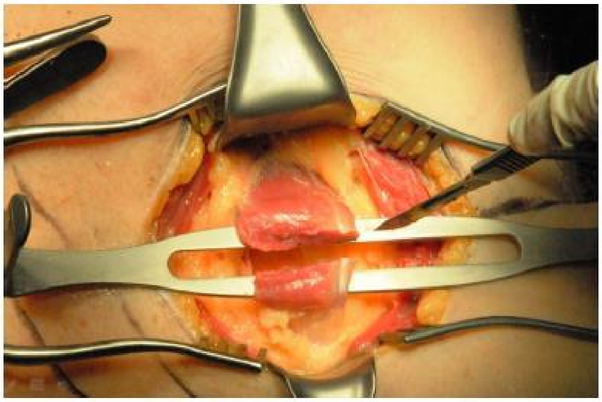
2. Identify landmarks for exposing the axillary artery (head at bottom of images)
a. Inferior edge of mid- clavicle
b. Deltopectoral groove

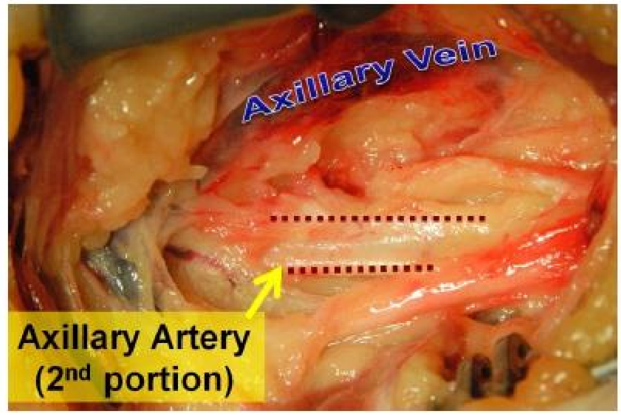


3. Have students cutdown on Axillary artery
a. Incision in deltopectoral groove inferior border of middle of clavicle to anterior axillary fold
b. Split the pectoralis major muscle in the direction of fibers, in dire emergencies the pectoralis major is taken down from its humeral insertion
c. With the pectoralis major retracted; the pectoralis minor is revealed



d. The pectoralis minor is divided to expose the second portion of the axillary artery (see image below)





4. Identify/discuss following structures:
a. Relationship of Brachial plexus, Artery and Vein

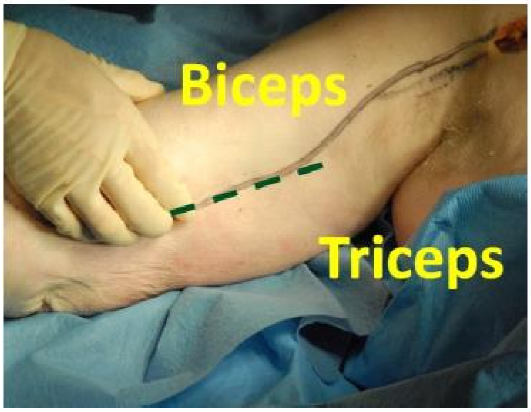
5. Debrief of Pearls and Pitfalls of Axillary Artery vascular control
a. A single axillary vein typically runs with the artery.
b. The brachial plexus is intimately associated with the axillary artery, and care must be taken to avoid nerve injury during quick exposure.
c. Slow, incomplete, or piecemeal division of pectoral muscles delays hemorrhage control.
d. Avoid this by inserting a finger or clamp under the entire muscle/tendon and dividing it quickly
e. An inadequate incision makes exposure and hemostasis difficult; a generous incision is warranted to ensure rapid vascular control.

RASP Case Two: Vascular Exposure of the Brachial Vessels

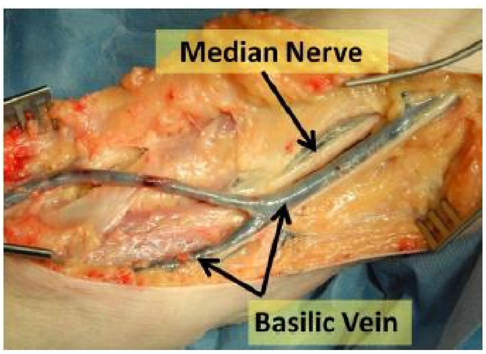
- 32 y/o male accidentally shot at close range with a hunting rifle in the left arm
- Reported to have large amount of bright red pulsatile blood at scene
- Active pulsatile bleeding from medial wound (Controlled with tourniquet)
- Absent distal pulses
- B/P = 100/68, HR = 120
- No other injuries

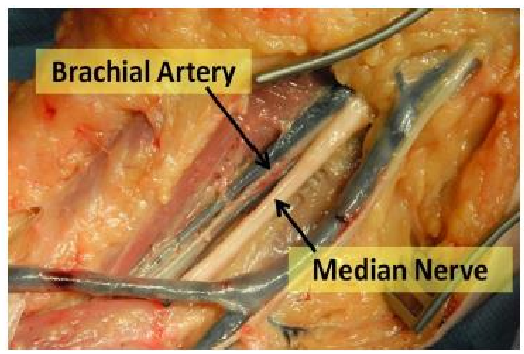
Teaching Objectives/Steps:

1. Identify the Landmarks
a. Triceps & Biceps Muscles
b. Bicepital groove



2. Expose the proximal brachial artery



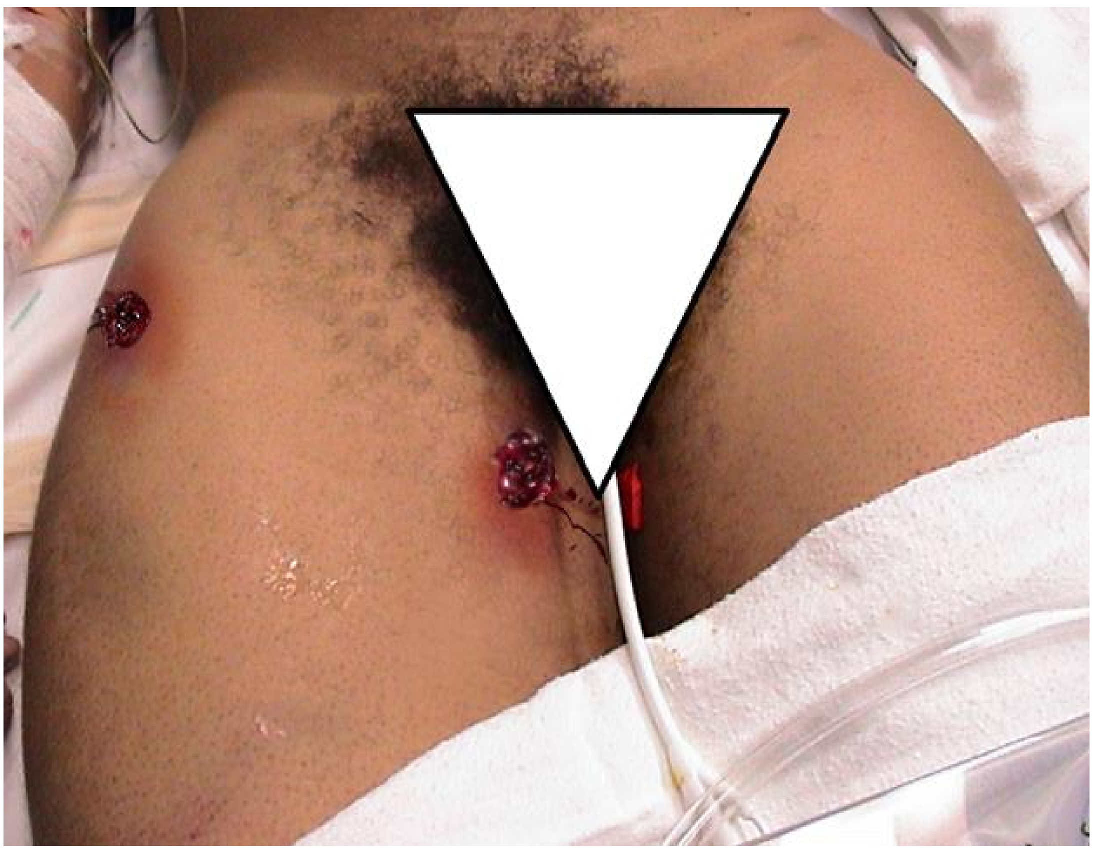


a. The median nerve lies directly over the brachial artery in the mid-arm and is superior to the basilic vein seen with the medial antebrachial cutaneous nerve inferior.
b. Further dissection exposes the brachial artery and its paired veins deep and superior to the median nerve.

4. Debrief of Pearls and Pitfalls Brachial Artery vascular control
a. In the mid-upper arm, the median nerve may be injured by careless dissection, as it runs directly on the artery.
b. Knowledge of the anatomic relationships of the median nerve to the artery and its closely adherent paired veins is important to prevent iatrogenic injury
c. An injured brachial or basilica vein can be resected and used as an arterial conduit.
d. Care should be taken not to harm the vein during dissection and harvest.
e. The brachial artery of a young, healthy patient is very vasoreactive and can be surprisingly small when in spasm.
f. If there is question as to whether the true brachial artery has been found, it should be followed proximally until doubt is removed.

RASP Case Three: Vascular Exposure of the Common Femoral, Superficial Femoral and Profunda Arteries

- 24 y/o male victim of a drive by shooting, sustaining a through and through gun shot wound to the Right mid thigh.
- He was reported to have a large amount of bright red pulsatile blood at the scene
- He was initially taken to a small community hospital without an in-house surgeon where his blood pressure was 80/50 and his heart rate was 140, and he was reported to have a markedly swollen thigh with active bleeding and no distal pulses. There are no other injuries.
- At the outside hospital a tourniquet was placed and he received 3000 cc of crystalloid and he is transferred to your facility now more than four hours after the injury on low dose norepinephrine with a blood pressure of 100/70 and a HR of 130, with a markedly swollen thigh and absent distal pulses.



Teaching Objectives/Steps:

1. Identify landmarks for exposing the femoral artery
a. Pubic tubercle, Anterior Superior Iliac crest
b. Inguinal Ligament

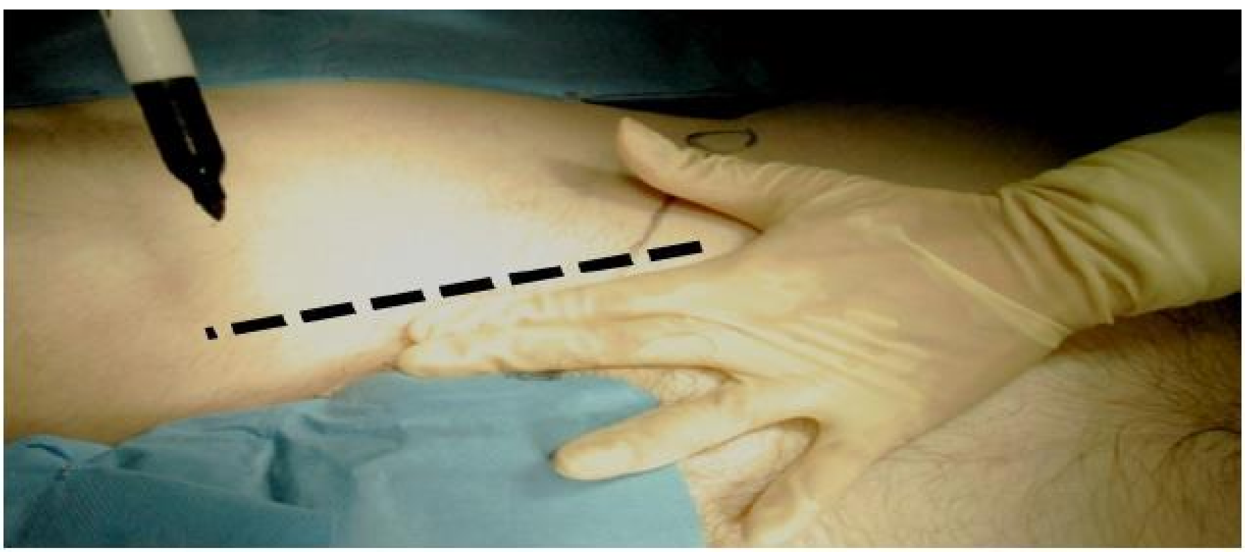
2. Have students cut down on Femoral artery
a. Incision directly over artery (using above landmarks) from above Inguinal Ligament to several inches below.
b. Open Femoral sheath on top of artery exposing common femoral and bifurcation
c. Deep dissection of the artery should be lateral to the saphenous vein and inguinal nodes

3. Identify/discuss following structures:
a. Relationship of Nerve, Artery, Vein, and Lymphatics
b. Circumflex iliac vessels

4. Expose Profunda and Superficial Femoral Artery
a. Proximal control of the profunda (place sling around origin of artery)

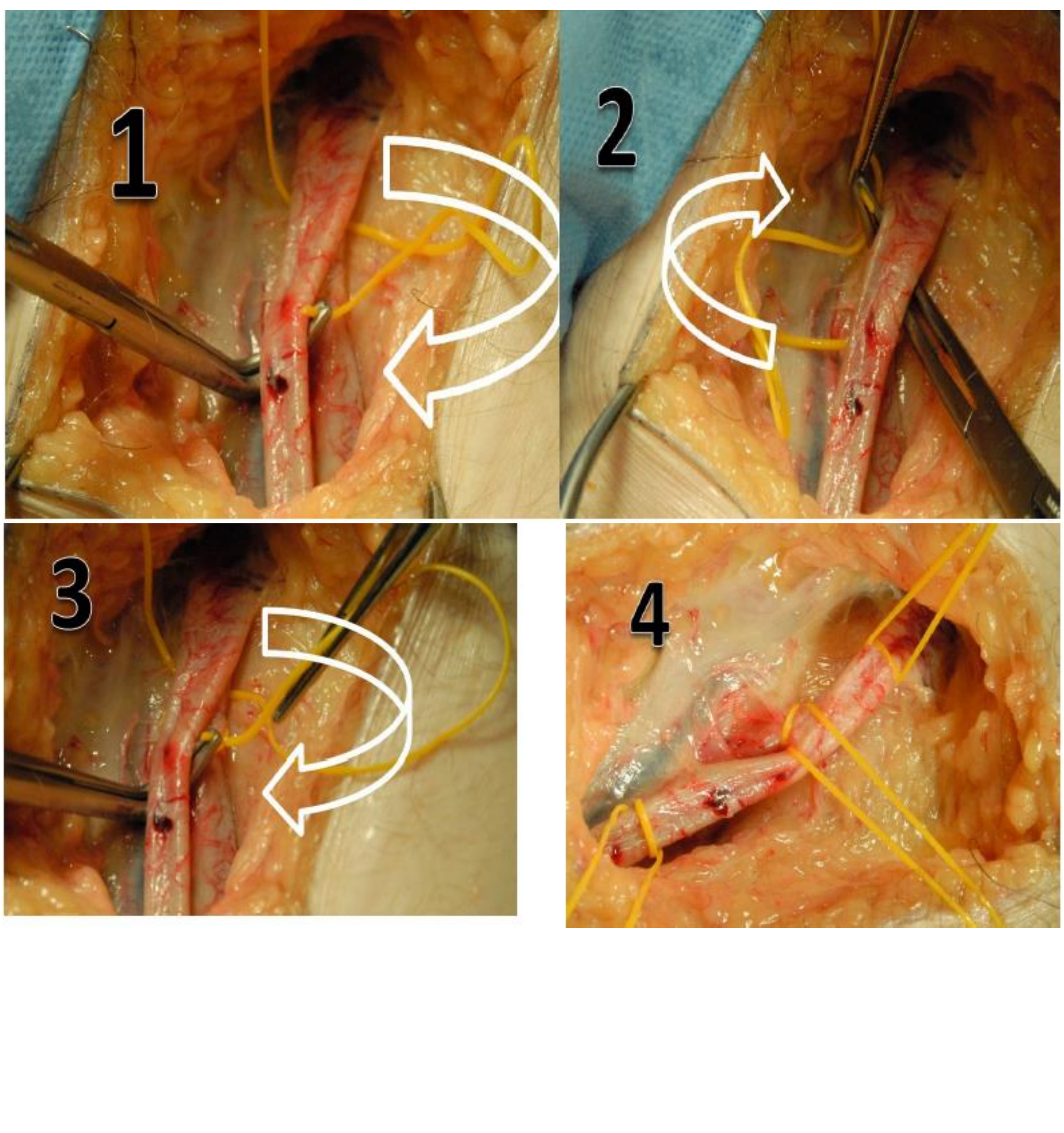
5. Expose several inches of SFA in the thigh.

Exposure of the Femoral Artery at the Groin:



Incision to expose Left Femoral Artery, opening femoral sheath on top of artery

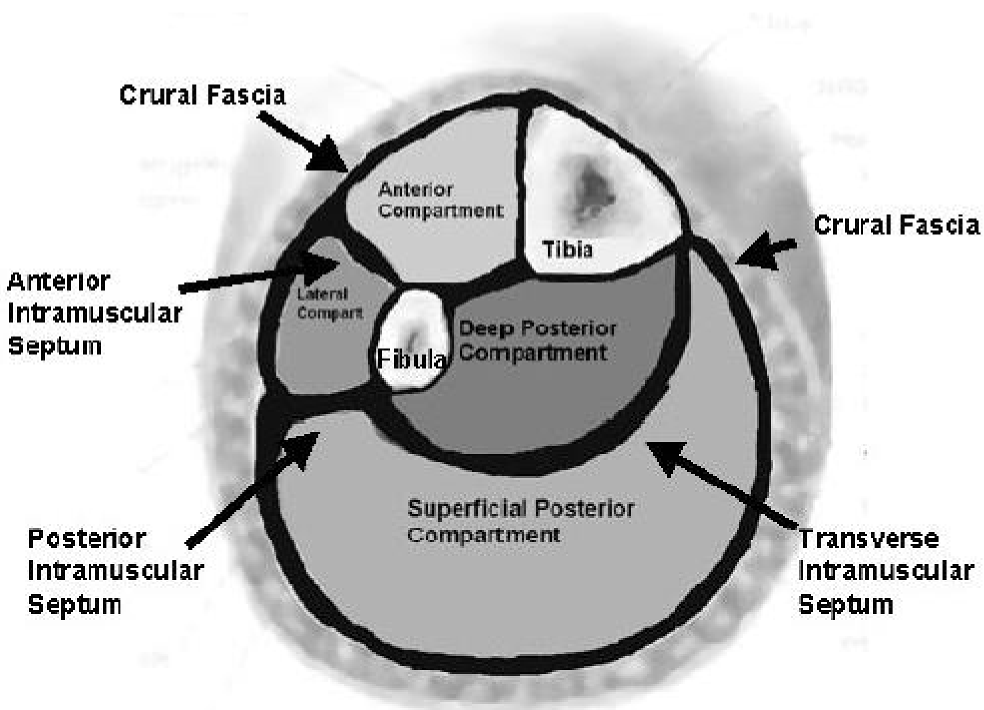
Proximal Control of the Profunda Artery:

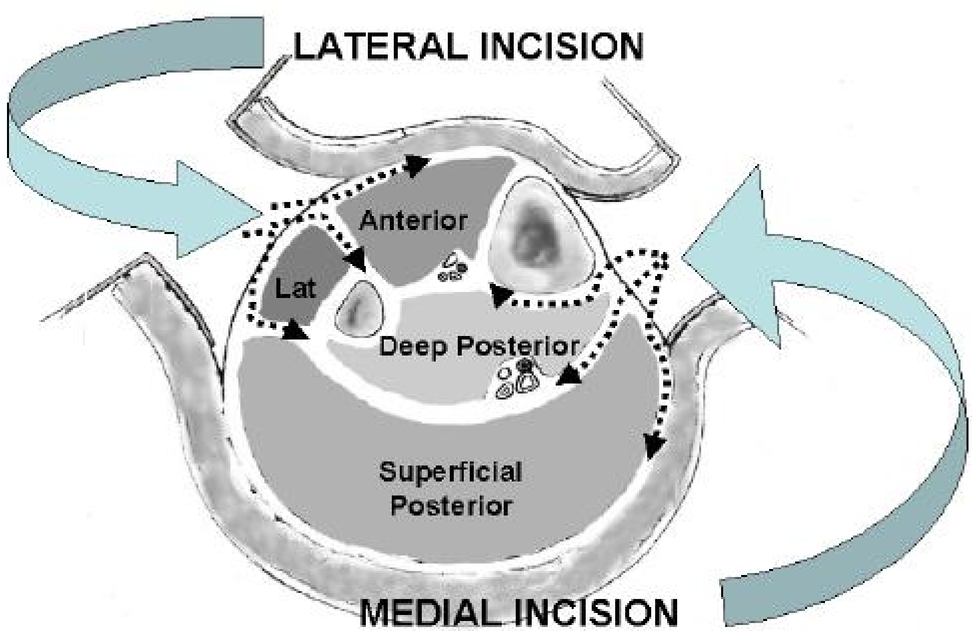


ASSET Case Four: Fasciotomy of the Lower Extremity (Two Incision – Four Compartment Fasciotomy)

Teaching Objectives/Steps:

1. Review the anatomy of the compartments of the lower leg and the landmarks for incisions.



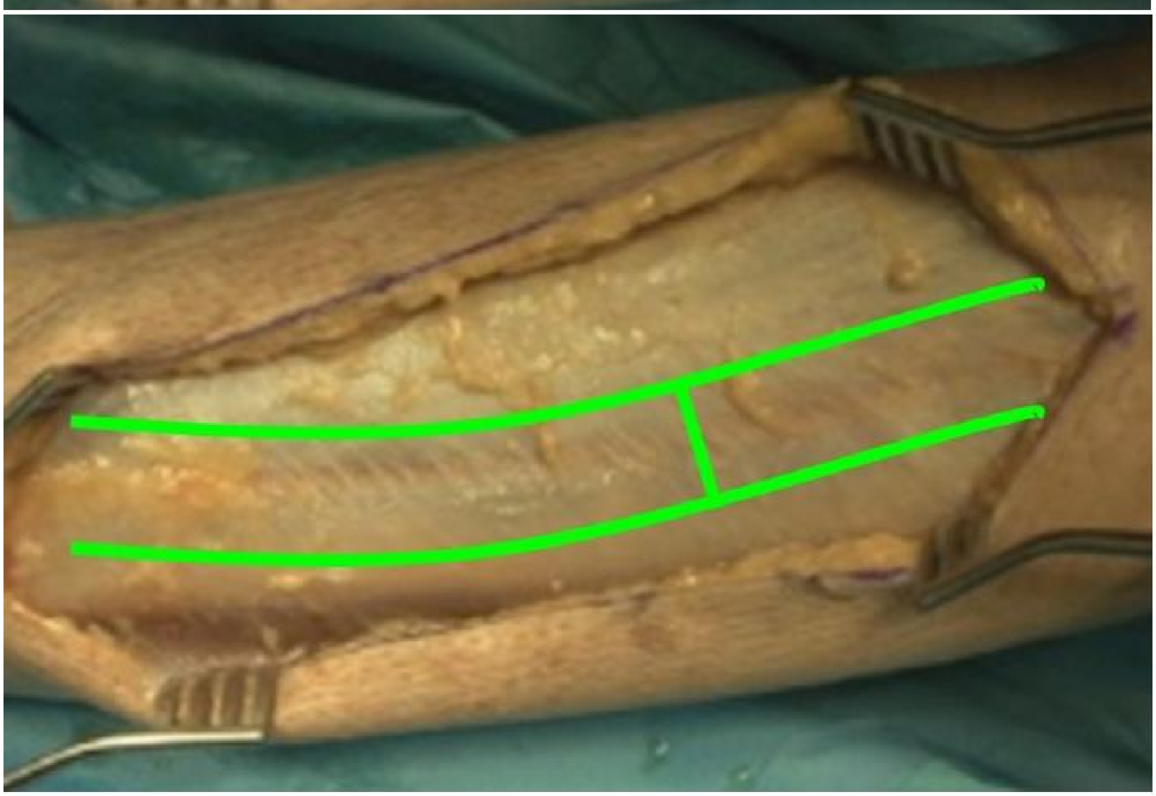


2. Perform Lateral Incision:

a. One finger in front of the fibula

b. Identify Intramuscular Septum

c. H-Shaped incision, extent of fasciotomy and skin incisions



3. Perform Medial Incision

a. One *Thumb behind the Tibia*
b. Identify & preserve the Saphenous Vein
c. Enter Deep posterior compartment by taking down the soleus fibers
d. Identification of neurovascular bundle confirms entry into deep posterior compartment
e. Extent of fasciotomy and skin incisions.

Debrief of Pearls and Pitfalls Lower Extremity Fasciotomy

a. Diagnosis of Compartment syndrome may be delayed or missed entirely.
b. Skin incision not extend far enough superiorly or inferiorly or may not be placed in the correct position.
c. Fasciotomy may not be completed. Incision of the fascial tissue may not extend far enough superiorly or inferiorly.
d. The anterior and posterior deep compartments are the most often missed compartments.

Section II: Evaluation Instructions and Surgical Technical Skills Definitions

Evaluation Instructions –

Each evaluation sheet is comprised of four sections: 1) Global evaluation – allows you to provide your overall sense of performance for each procedure; 2) Surgical Technique points – allows you to score surgical skills/technique; 3) Surgical task points – allows you to score whether the participant has completed the necessary steps to adequately perform each procedure and 4) Expert Discriminatory sections – allows you to further define behaviors that denote either an expert or novice surgeon.

In addition, we ask you to fill out the date on which you evaluated the procedure, the video file number (if applicable) and your initials. At the end of the sheet there is also a section to provide further information such as a description of cadaver body habitus and whether the cadaver had normal or variant anatomy.

The Global Ratings:

1) Provides several pre-selected possibilities (linked to a Likert Scale) that ranks the surgeons technical performance of the RASP procedure that you are evaluating. Select the description that best identifies your evaluation of the participants surgical skill level.

2) Complete Overall Global Rating score (as a percentage) that reflects your judgment of the participants' surgical technical skills.

Surgical Technique:

1) Scored using the 1-5 scale linked with descriptors {(5) Every time (4) Almost every time (3) Sometimes (2) Occasionally (1) Never} shown at the bottom of the page. There is also an option to document if certain skulls were unable to be determined (UTA).

2) In general, each technique point describes either a preferred or unwanted behavior. The Likert Scale ranks how often the individual repeats that behavior during the procedure, in descending order.

Completion of Surgical Tasks (Yellow Heading Bar):

1) Evaluate each of the tasks identified for the procedure as yes/no if completed or UTA if Unable to Assess.

Surgical Technical Skill in the Operative Field:

1) This section details surgical skill associated with the skin incision, use of the entirety of the surgical field and how the surgeon's operating shifts throughout the operating field in a logical and systematic manner that infers intimate knowledge of the relevant anatomy.

Technical Skill in Instrument Use

1) This evaluation highlights aspects of surgical skill related to instrument use and choices e.g. how the instruments are held, how they are applied to the operating field, and how often and appropriate are the changes in instruments.

Evaluation Sheet Examples

AXILLARY ARTERY EXPOSURE GLOBAL RATING (circle one)**:**

Technical Skills for Exposing Axillary Artery:

1	2	3	4	5	UTA*
The participant's technical skills were well below expected with much wasted moves and very poor tissue handling.	The participant demonstrated below average technical skills with lots of wasted movements and errors in tissue handling.	The participant demonstrated average technical skills with some 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 superior technical skills with no wasted movements and proper respect for tissues.	

Overall Understanding of the Surgical Anatomy of the Axillary Region:

1	2	3	4	5	UTA*
Inadequate knowledge of the regional anatomy. Unable to identify major structures and their relationships.	Knowledge of regional anatomy is below average. Can name most of the major structures but, requires some prompting.	Average understanding of the anatomy. May not be able to immediately point out or name all of the structures but can do so with minimal prompting.	Above average understanding of anatomy. Able to point out all of the relevant structures without prompting.	Superior grasp of anatomy and knows the minutia. Should be teaching anatomy class.	

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

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

EXPOSURE OF AXILLARY

DATE INITIALS: VIDEO FILE #:

Technique points	Score 1-5	UTA
Exposes arteries by dissecting directly on anterior surface		
Manipulates artery by grasping adventitia		
Uses instruments properly		
Positions body to use instruments to best advantage		
Proceeds at appropriate pace with economy of movement		
Handles tissue well with minimal damage		
Creates an adequate visual field for procedure		
Communicates clearly and consistently		
Performs procedure without unnecessary dissection		
Continually progresses towards the end goal		

Surgical tasks for Axillary A. exposure	**Yes**	**No**	**UTA**
Initial skin incision is adequate to perform exposure			
Splitting or dividing Pectoralis Major			
Identification of Pectoralis Minor			
Division of the Pectoralis Minor			
Correctly identifies Axillary Artery			
Correctly identifies Axillary Vein			
Correctly identifies brachial plexus			
Controls the Axillary artery proximal to injury			

Error: Incorrectly identifies the Axillary artery and does not recognize or correct error	
Error: Incorrectly identifies the Axillary artery but is able to recognize and correct	

***Technique point Score 1-5: (5) Every time (4) Almost every time (3) Sometimes (2) Occasionally (1) Never**

Expert Discriminator Operative Field Maneuvers for Axillary Artery Exposure

	Yes	**No**
Operates through 'key-hole' or too small a skin incision		
Operates through incision-space		
Excessive dissection		
Pointless digging and shifting around in surgical field		
Has a logical operating sequence		
Lacks anatomical knowledge		

Expert Discriminatory Instrument Use for Axillary Artery Exposure

	Yes	**No**
Improper instrument use (e.g. back-handed use)		
Incorrect instrument holding (e.g. forceps too near tips, thumb through scissors handle)		
Scalpel use: multiple tentative cuts or cuts tangentially		
Switches instruments more than you would		
Uses scissors less than you would		
Dedicated use of a single instrument.		

BRACHIAL ARTERY EXPOSURE GLOBAL RATING (circle one)**:**

Technical Skills for Exposing Brachial Artery:

1	2	3	4	5	UTA*
The participant's technical skills were well below expected with much wasted moves and very poor tissue handling.	The participant demonstrated below average technical skills with lots of wasted movements and errors in tissue handling.	The participant demonstrated average technical skills with some 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 superior technical skills with no wasted movements and proper respect for tissues.	

Overall Understanding of the Surgical Anatomy of the Brachial Region:

1	2	3	4	5	UTA*
Inadequate knowledge of the regional anatomy. Unable to identify major structures and their relationships.	Knowledge of regional anatomy is below average. Can name most of the major structures but, requires some prompting.	Average understanding of the anatomy. May not be able to immediately point out or name all of the structures but can do so with minimal prompting.	Above average understanding of anatomy. Able to point out all of the relevant structures without prompting.	Superior grasp of anatomy and knows the minutia. Should be teaching anatomy class.	

This participant is ready to perform exposure and control the Brachial 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

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

EXPOSURE OF BRACHIAL	DATE	INITIALS:	VIDEO FILE #:

**Technique points*		
	Score 1-5	***UTA***
Exposes arteries by dissecting directly on anterior surface		
Manipulates artery by grasping adventitia		
Uses instruments properly		
Positions body to use instruments to best advantage		
Proceeds at appropriate pace with economy of movement		
Handles tissue well with minimal damage		
Creates an adequate visual field for procedure		
Communicates clearly and consistently		
Performs procedure without unnecessary dissection		
Continually progresses towards the end goal		

Surgical tasks for Brachial A. exposure			
	Yes	**No**	**UTA**
Initial skin incision is adequate to perform exposure			
Identifies Biceps and Triceps muscle			
Create plane of dissection between the Bicep and Triceps			
Correctly identifies Median Nerve			
Retracts and protects Median Nerve			
Correctly identifies Brachial Artery			
Dissects Brachial Artery away from venae comites			
Controls Brachial Artery with vessel loop			

Error: Incorrectly identifies the Brachial artery and does not recognize or correct error	
Error: Incorrectly identifies the Brachial artery but is able to recognize and correct	

***Technique point Score 1-5: (5) Every time (4) Almost every time (3) Sometimes (2) Occasionally (1) Never**

Expert Discriminator Operative Field Maneuvers for Brachial Artery Exposure

	Yes	**No**
Operates through 'key-hole' or too small a skin incision		
Operates through incision-space		
Excessive dissection		
Pointless digging and shifting around in surgical field		
Has a logical operating sequence		
Lacks anatomical knowledge		

Expert Discriminatory Instrument Use for Brachial Artery Exposure

	Yes	**No**
Improper instrument use (e.g. back-handed use)		
Incorrect instrument holding (e.g. forceps too near tips, thumb through scissors handle)		
Scalpel use: multiple tentative cuts or cuts tangentially		
Switches instruments more than you would		
Uses scissors less than you would		
Dedicated use of a single instrument.		

FEMORAL ARTERY EXPOSURE GLOBAL RATING (circle one)**:**

Technical Skills for Exposing Femoral Artery:

1	2	3	4	5	UTA*
The participant's technical skills were well below expected with much wasted moves and very poor tissue handling.	The participant demonstrated below average technical skills with lots of wasted movements and errors in tissue handling.	The participant demonstrated average technical skills with some 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 superior technical skills with no wasted movements and proper respect for tissues.	

Overall Understanding of the Surgical Anatomy of the Femoral Region:

1	2	3	4	5	UTA*
Inadequate knowledge of the regional anatomy. Unable to identify major structures and their relationships.	Knowledge of regional anatomy is below average. Can name most of the major structures but, requires some prompting.	Average understanding of the anatomy. May not be able to immediately point out or name all of the structures but can do so with minimal prompting.	Above average understanding of anatomy. Able to point out all of the relevant structures without prompting.	Superior grasp of anatomy and knows the minutia. Should be teaching anatomy class.	

This participant is ready to perform exposure and control the Femoral 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

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

EXPOSURE OF FEMORAL	DATE	INITIALS:	VIDEO FILE #:

***Technique points**		
	Score 1-5	***UTA***
Exposes arteries by dissecting directly on anterior surface		
Manipulates artery by grasping adventitia		
Uses instruments properly		
Positions body to use instruments to best advantage		
Proceeds at appropriate pace with economy of movement		
Handles tissue well with minimal damage		
Creates an adequate visual field for procedure		
Communicates clearly and consistently		
Performs procedure without unnecessary dissection		
Continually progresses towards the end goal		

Surgical tasks for Femoral A. exposure			
	Yes	**No**	**UTA**
Initial skin incision is adequate to perform exposure			
Correctly identifies Common Femoral Artery			
Correctly identifies Common Femoral Vein			
Correctly identifies Profunda Femoral Branch			
Correctly identifies Superficial Femoral Artery			
Controls Common Femoral Artery with vessel loop			
Controls Profunda Femoral Artery with vessel loop			
Controls Superficial Femoral Artery with vessel loop			

Error: Incorrectly identifies the CFA, SFA, or PFA and does not recognize or correct error	
Error: Incorrectly identifies the CFA, SFA, or PFA but is able to recognize and correct	

***Technique point Score 1-5: (5) Every time (4) Almost every time (3) Sometimes (2) Occasionally (1) Never**

Expert Discriminator Operative Field Maneuvers for Femoral Artery Exposure

	Yes	**No**
Operates through 'key-hole' or too small a skin incision		
Operates through incision-space		
Excessive dissection		
Pointless digging and shifting around in surgical field		
Has a logical operating sequence		
Lacks anatomical knowledge		

Expert Discriminatory Instrument Use for Femoral Artery Exposure

	Yes	**No**
Improper instrument use (e.g. back-handed use)		
Incorrect instrument holding (e.g. forceps too near tips, thumb through scissors handle)		
Scalpel use: multiple tentative cuts or cuts tangentially		
Switches instruments more than you would		
Uses scissors less than you would		
Dedicated use of a single instrument.		

LOWER EXTREMETY FASCIOTOMY GLOBAL RATING (circle one)**:**

Technical Skills for Displayed by participant during Fasciotomy:

1	**2**	**3**	**4**	**5**	**UTA***
The participant's technical skills were well below expected with much wasted moves and very poor tissue handling.	The participant demonstrated below average technical skills with lots of wasted movements and errors in tissue handling.	The participant demonstrated average technical skills with some 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 superior technical skills with no wasted movements and proper respect for tissues.	

Overall Understanding of the Surgical Anatomy required for performing Fasciotomy of the lower extremity:

1	**2**	**3**	**4**	**5**	**UTA***
Inadequate knowledge of the regional anatomy. Unable to identify major structures and their relationships.	Knowledge of regional anatomy is below average. Can name most of the major structures but, requires some prompting.	Average understanding of the anatomy. May not be able to immediately point out or name all of the structures but can do so with minimal prompting.	Above average understanding of anatomy. Able to point out all of the relevant structures without prompting.	Superior grasp of anatomy and knows the minutia. Should be teaching anatomy class.	

This participant is ready to perform a two incision four compartment Fasciotomy of the lower extremity:

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

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

LOWER EXTREMITY FASCIOTOMY	DATE:	INITIALS:	VIDEO FILE #:

LATERAL leg incision landmarks:			
	Yes	**No**	**UTA**
The lateral Incision is marked one-two fingers in front of the fibula (1.5-3.0 cm)			
Upper end of incision 2-3 fingers (3.0-6.0 cm) from tibial plateau (TP)			
Lower end of incision 2-3 fingers (3.0-6.0 cm) from Lat. malleolus			

MEDIAL leg incision landmarks:			
	Yes	**No**	**UTA**
The Medial Incision is marked one Thumb behind the tibia (1.0-3.0 cm)			
Upper end of incision 2-3 fingers (3.0-6.0 cm) from tibial plateau (TP)			
Lower end of incision 2-3 fingers (3.0-6.0 cm) from Med. malleolus			

LATERAL Incision surgical tasks			
	Yes	**No**	**UTA**
Identifies Intermuscular septum			
Mentions perforating vessels as way to find IM septum			
Correctly identifies anterior and lateral compartments			
Uses “H-Shaped” incision to open fascia			
Under-runs fascia with closed scissor tips			
Opens fascia with partially closed scissor tips			
Points tips of scissors away from septum			
Relates necessity to avoid injury to underlying nerves			
Opens fascia over anterior compartment completely, within 3 cm of fibular head and lateral maleolus			
Opens fascia over lateral compartment completely			

MEDIAL Incision surgical tasks			
	Yes	**No**	**UTA**
Identifies and relates need to preserve greater saphenous vein and to ligate tributaries			
Correctly identify superficial posterior compartment (SPC)			
Opens entire length of fascia over superficial post compartment, within 3 cm of tibial plateau and medial maleolus			
Identifies contents of SPC:			
gastrocnemius			
soleus muscles			
Takes down soleus fibers from underside of tibia to enter Deep Post Compartment (DPC)			
Identifies the neurovascular bundle in the DPC			

****Technique Points***	**Score 1-5**	**UTA**
Uses instruments properly		
Positions body to use instruments to best advantage		
Proceeds at appropriate pace with economy of movement		
Creates an adequate visual field for procedure		
Communicates clearly and consistently		
Performs procedure without unnecessary dissection		
Continually progresses towards the end goal		

Error: Incorrectly identifies the intermuscular septum and does not recognize or correct error	
Error: Incorrectly identifies the intermuscular septum, but is able to recognize and correct	
Error: Fails to open compartments along the entire length	
Error: Fails to decompress the deep posterior compartment	
Error: Fails to decompress the anterior compartment	

***Technique point Score 1-5: (5) Every time (4) Almost every time (3) Sometimes (2) Occasionally (1) Never**

Expert Discriminator Operative Field Maneuvers for Lower Extremity Fasciotomy

	Yes	No
Operates through 'key-hole' or too small a skin incision		
Operates through incision-space		
Excessive dissection		
Pointless digging and shifting around in surgical field		
Has a logical operating sequence		
Lacks anatomical knowledge		

Expert Discriminatory Instrument Use for Lower Extremity Fasciotomy

	Yes	No
Improper instrument use (e.g. back-handed use)		
Incorrect instrument holding (e.g. forceps too near tips, thumb through scissors handle)		
Scalpel use: multiple tentative cuts or cuts tangentially		
Switches instruments more than you would		
Uses scissors less than you would		
Dedicated use of a single instrument.		

Technique Point Definitions

Exposes artery by dissecting directly on anterior surface:
Participant will use sharp dissection (eg Metz or scalpel) to incise the fascia and adventitia on the anterior surface of the artery thus avoiding smaller arteries that branch from the sides of the artery.

Manipulates artery by grasping adventitia:
The participant will use forceps to gently pull on or manipulate vascular structures by the adventitia. This will allow the participant to manipulate the artery, gaining an advantageous position for dissection. Any forceful movement or grasping of vascular tissue proper is considered incorrect.

Uses instruments properly:
Of the instruments used, this section will discuss proper handling of the 10 blade scalpel, Metzenbaum scissors, surgical forceps and Weitlaner retractors. The scalpel should be held similarly to a pencil between the thumb and second finger with the forefinger guiding it. Curved Metz should be held so that the curve is facing the same direction as the palmar surface of the participant’s hand. The fingers should not be fully inserted within the handles of the scissors allowing for finer dexterous control. In addition, while using instruments such as Metz scissors or right angle forceps the participant should not situate themselves so that there arm and hand are contorted into a “back-handed” position. Forceps should not be held too close to the teeth. Weitlaner retractors should be quickly placed creating a larger area of exposure. Prolonged placement and repeated movement of retractors is considered incorrect.

Positions body to best advantage:
The participant should recognize their ability to relocate in relation to the cadaver in order to gain the most advantageous position for dissection. Back-handed use of surgical instruments is an indication of poor body position.

Proceeds at appropriate pace with economy of movement:
The objective of these surgical procedures is to gain immediate access and control of the artery thus avoiding unnecessary blood loss. Any hesitation during exposure or unconfident movement is considered to an inefficient pace. Any purposeless dissection is also considered inefficient. Instead, once the participant has gained access to the vessel no time is wasted identifying it and placing a loop around it immediately.

Creates an adequate visual field:
The participant is aware of the appropriate anatomical landmarks and is aware of the most efficient area to begin dissection and exposure. The initial incision is of correct length and placement so that the participant is not dissecting in a “hole” or the wrong area. Other ways to create an adequate visual field are effective use of retractors and correct positioning of the patient.

Communicates clearly and consistently:
In the beginning of each procedure the participant is told to keep a rolling narrative that describes their dissection process and the logic behind it. Prolonged silence or inadequate definition is considered to be incorrect.

Performs procedure without unnecessary dissection:
Time should not be wasted by the participant identifying anatomical structures or dissecting too cautiously.

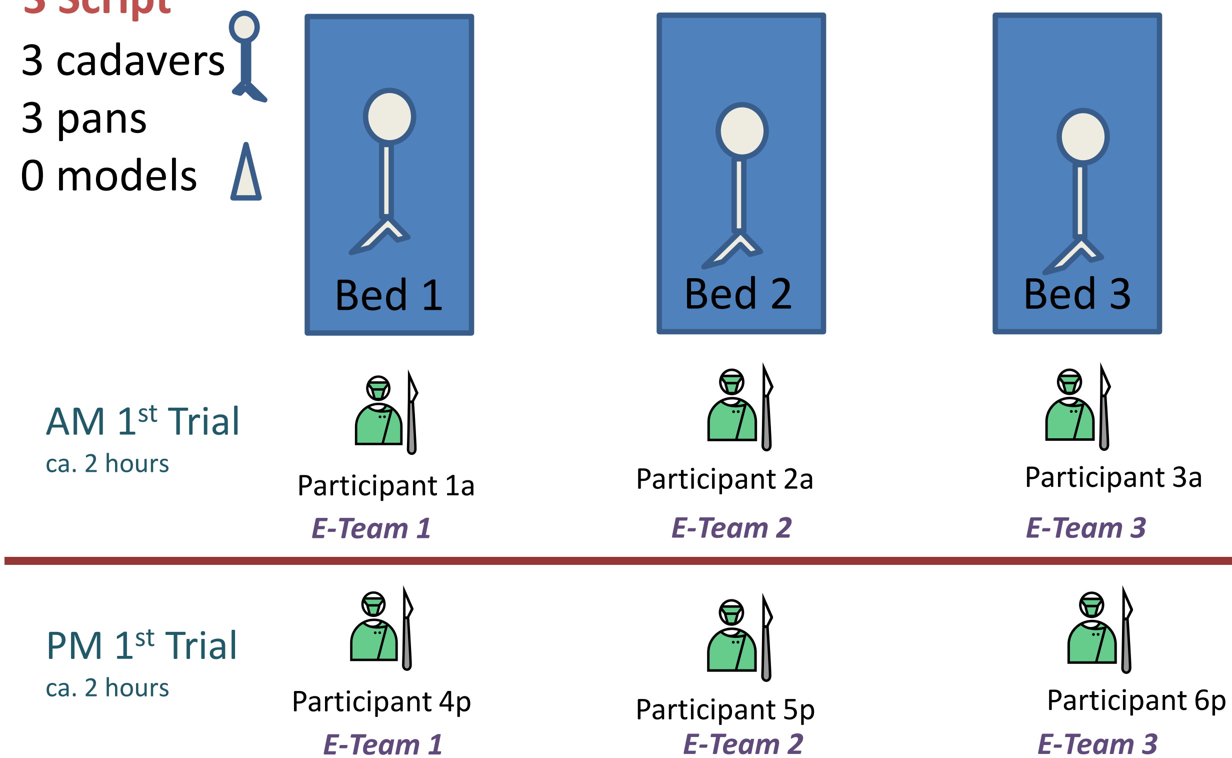
Continually progresses towards the end goal:
This technique really looks at the procedure as a whole. The participant uses their clinical and anatomical knowledge to quickly decide where the most appropriate area is to begin dissection, the initial skin incision is an adequate length (meaning that they can gain access to the artery immediately), once surgery begins they immediately identify and loop the artery all while using appropriate surgical instruments that are available to them.

Phase 2 PRE Scenario

Rules of the scenario:
- **2 sessions/day (AM & PM); 1 Trial/day (1st Trial)**
- Each cadaver must be used twice.
- 1 cadaver/participant during each session

6 Participants
3 Evaluators
3 Script

3 cadavers
3 pans
0 models



Phase 2 POST Scenario

6 Participants
3 Evaluators
3 Script

3 cadavers
3 pans
6 models

Rules of the scenario:

- **2 sessions/day (AM & PM); 2 Trials/session (1st and 2nd)**
- 3 participants, 3 E-Teams, and 3 beds operational per trial
- 3 participants must start on cadavers & 3 must start on models
- Each participant must have 1 trial with cadaver and 1 with model
- No participant can be at the same bed or with the same E-Team for both trials
- Cadaver beds must stay cadaver beds (Cadaver must be used twice, but may *not* be used at the same time).

	Bed 1	Bed 2	Bed 3	Bed 4	Bed 5
AM 1st Trial Ca. 2 hours	Participant 1a *E-Team 1*	Participant 2a *E-Team 2*		Participant 3a *E-Team 3*	
AM 2nd Trial Ca. 1.5 hours			Participant 3a *E-Team 3*	Participant 1a *E-Team 1*	Participant 2a *E-Team 2*
PM 1st Trial Ca. 2 hours	Participant 4p *E-Team 3*			Participant 5p *E-Team 1*	Participant 6p *E-Team 2*
PM 2nd Trial Ca. 1.5 hours		Participant 5p *E-Team 1*	Participant 6p *E-Team 2*	Participant 4p *E-Team 3*	

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.

No study procedure will take place until you have decided whether or not you wish to participate. If you agree to participate in this study, you will be asked to sign this Informed Consent Form.

There are three phases in this study.
In Phase I, we will make video recordings, and conduct interviews with 10 expert and 10 novice surgeons performing ASSET vascular access and control procedures.
In Phase II, 40 surgeons who have never been through the ASSET training curriculum will be recruited to do so, will be trained in cohorts of 10, using the standard unpreserved cadaver (dead human body) training models and non-live-tissue physical models, and then recalled at 12 (20 participants) or 18 months (20 participants) for reassessment on both the cadaveric and physical models.
In Phase III, 40 surgeons who participated in ASSET training 2 to 5 years ago using the standard, cadaveric model-based curriculum, will be recalled for retesting using the assessment instruments developed in Phase I and used in Phase II, including correlation with interval training and experience using ASSET procedures, to assess degradation/retention timing and patterns.

WHAT ARE MY RESPONSIBILITIES IF I TAKE PART IN THIS RESEARCH?
As a participant in this study you will be asked to complete all selected ASSET surgical procedures as described above. You will be video-recorded and your performance will be evaluated according to study criteria. Your identity will remain confidential. If you wish to withdraw from the study, you should contact the Principal Investigator or study staff.

POTENTIAL RISKS/DISCOMFORTS:
There is a risk of breach of confidentiality associated with study participation. In order to minimize this risk, we will keep all study related materials in a secure, locked office on a password protected computer.

There may be risks in this study which are not yet known.

POTENTIAL BENEFITS
You will not benefit directly from your participation in this study, other than receiving training in the ASSET Study procedures.

ALTERNATIVES TO PARTICIPATION
This is not a treatment study. Your alternative is to not take part. No one should influence or pressure you to be in this study. Your decision to be in the study, or to leave the study early, will not affect your job or job benefits.

COSTS TO PARTICIPANTS
It will not cost you anything to take part in this study

PAYMENT TO PARTICIPANTS
Travel Costs, Government approved Per Diem Costs, Hotel accommodation (where needed) and an Honorarium to cover loss of clinical revenue during participation in the ASSET Study will be covered by Study funding for each participant. For Military or federal employees, study participation must be done during official off-duty time in order for subjects to receive compensation. The Honoraria will be $ 500 for residents and for Fellows for your 3 study visits ($200 will be paid after the initial visits and the balance on completion of the 12 or 18 month follow up) and $300 for a single study visit by previously ASSET trained Surgeons who have already completed the full ASSET Course. In addition, full ASSET course tuition ($500) will be provided for 50 surgeons (Residents and Fellows) who may wish to complete the full ASSET course.

CONFIDENTIALITY AND ACCESS TO RECORDS
Your confidentiality will be protected during and after participating in the study as required by law and according to any policies the study center or sponsor may have. Be aware that your study records (your signed consent form, and other information) will be shared and copied as needed for the study. Organizations that may inspect and copy your information include the Sponsor, IRB and other representatives of this organization

The data from the study may be published. However, you will not be identified by name. People designated from the institutions where the study is being conducted and people from the sponsor will be allowed to inspect sections of your medical and research records related to the study. Everyone using study information will work to keep your personal information confidential. Your personal information will not be given out unless required by law

Representatives of the U.S. Army Medical Research and Materiel Command are authorized to review research records as part of their responsibility to protect human research volunteers. Research records will be stored in a confidential manner so as to protect the confidentiality of your information.

RIGHT TO WITHDRAW
Your participation in this study is voluntary. You do not have to take part in this research. You are free to withdraw your consent at anytime. Refusal to take part or to stop taking part in the study will involve no penalty or loss of benefits to which you are otherwise entitled. If you decide to stop taking part, or if you have questions, concerns, or complaints, or if you need to report a medical injury related to the research, please contact the investigator, Dr.Colin Mackenzie at 410-328-7488.

There are no adverse consequences (physical, social, economic, legal, or psychological) of your decision to withdraw from the research.

If you are an employee, your employment status or academic standing at UMB will not be affected by your participation or non-participation in this study.
If you withdraw from this study, already collected data may not be removed from the study database.

You will be told of any significant new findings which develop during the study which may affect your willingness to participate in the study.

CAN I BE REMOVED FROM THE RESEARCH?
The person in charge of the research study or the sponsor can remove you from the research study without your approval. Possible reasons for removal include failure to follow instructions of the research staff, or if the principal investigator decides that the research study is no longer in your best interest. The sponsor can also end the research study early. The Principal Investigator or study staff will tell you about this and you will have the chance to ask questions if this were to happen.

UNIVERSITY STATEMENT CONCERNING RESEARCH RISKS

The University is committed to providing participants in its research all rights due them under State and federal law. You give up none of your legal rights by signing this consent form or by participating in the research project. This research has been reviewed and approved by the Institutional Review Board (IRB). Please call the Institutional Review Board (IRB) if you have questions about your rights as a research participant.

The research described in this consent form has been classified as minimal risk by the IRB of the University of Maryland, Baltimore (UMB). The IRB is a group of scientists, physicians, experts, and other persons. The IRB's membership includes persons who are not affiliated with UMB and persons who do not conduct research projects. The IRB's decision that the research is minimal risk does not mean that the research is risk-free. You are assuming risks of injury as a result of research participation, as discussed in the consent form.

If you are harmed as a result of the negligence of a researcher, you can make a claim for compensation. If you have questions, concerns, complaints, or believe you have been harmed through participation in this research study as a result of researcher negligence, you can contact members of the IRB or the staff of the Human Research Protections Office (HRPO) to ask questions, discuss problems or concerns, obtain information, or offer input about your rights as a research participant. The contact information for the IRB and the HRPO is:

University of Maryland School of Medicine
Human Research Protections Office
BioPark I, 800 W. Baltimore Street, Suite 100
Baltimore, MD 21201
410-706-5037

Signing this consent form indicates that you have read this consent form (or have had it read to you), that your questions have been answered to your satisfaction, and that you voluntarily agree to participate in this research study. You will receive a copy of this signed consent form.

If you agree to participate in this study, please sign your name below.

____
Participant's Signature

Date:______________________________

____
Investigator or Designee Obtaining Consent Signature

Date:______________________________

APPENDIX VII Surgeon Demographics, Experience and Self-Confidence Questionnaire

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

Evaluation of Surgical Confidence (Pre-ASSET training)

Please indicate the number that best represents your confidence level for your understanding of the surgical anatomy in the following regions:

1	**2**	**3**	**4**	**5**
No confidence.				**Quite a lot of confidence.**

Shoulder /axillary region:	1	2	3	4	5
The arm:	1	2	3	4	5
The forearm:	1	2	3	4	5
The inguinal region:	1	2	3	4	5
The lower extremity:	1	2	3	4	5

Please indicate the number that best represents your comfort level with performing each of the following surgical procedures for <u>traumatic injury</u> *independently*.

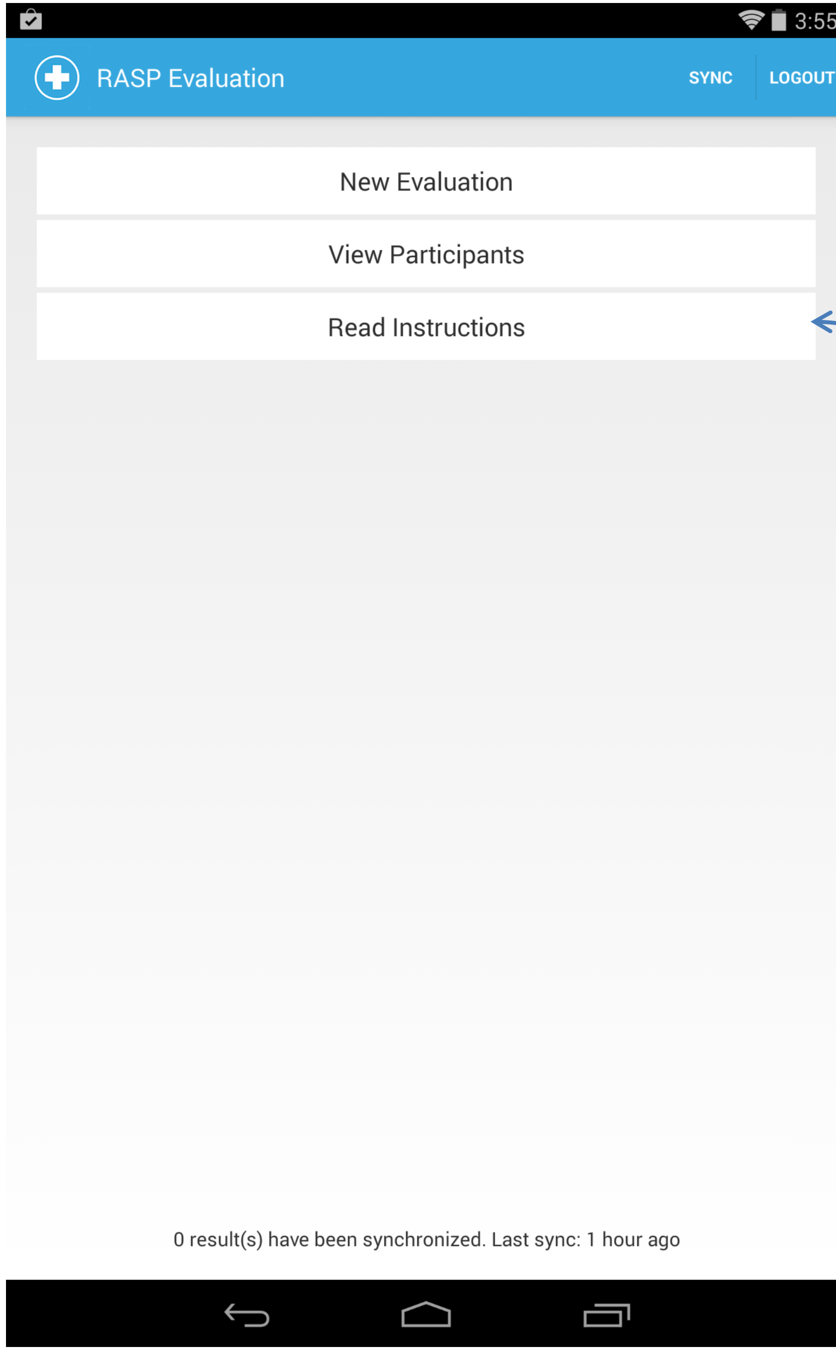
1	**2**	**3**	**4**	**5**
No confidence. I would need significant guidance		**My confidence wavers with this procedure. I would like**		**Quite a lot of confidence. I am sure of what I am doing,**

		supervision.		

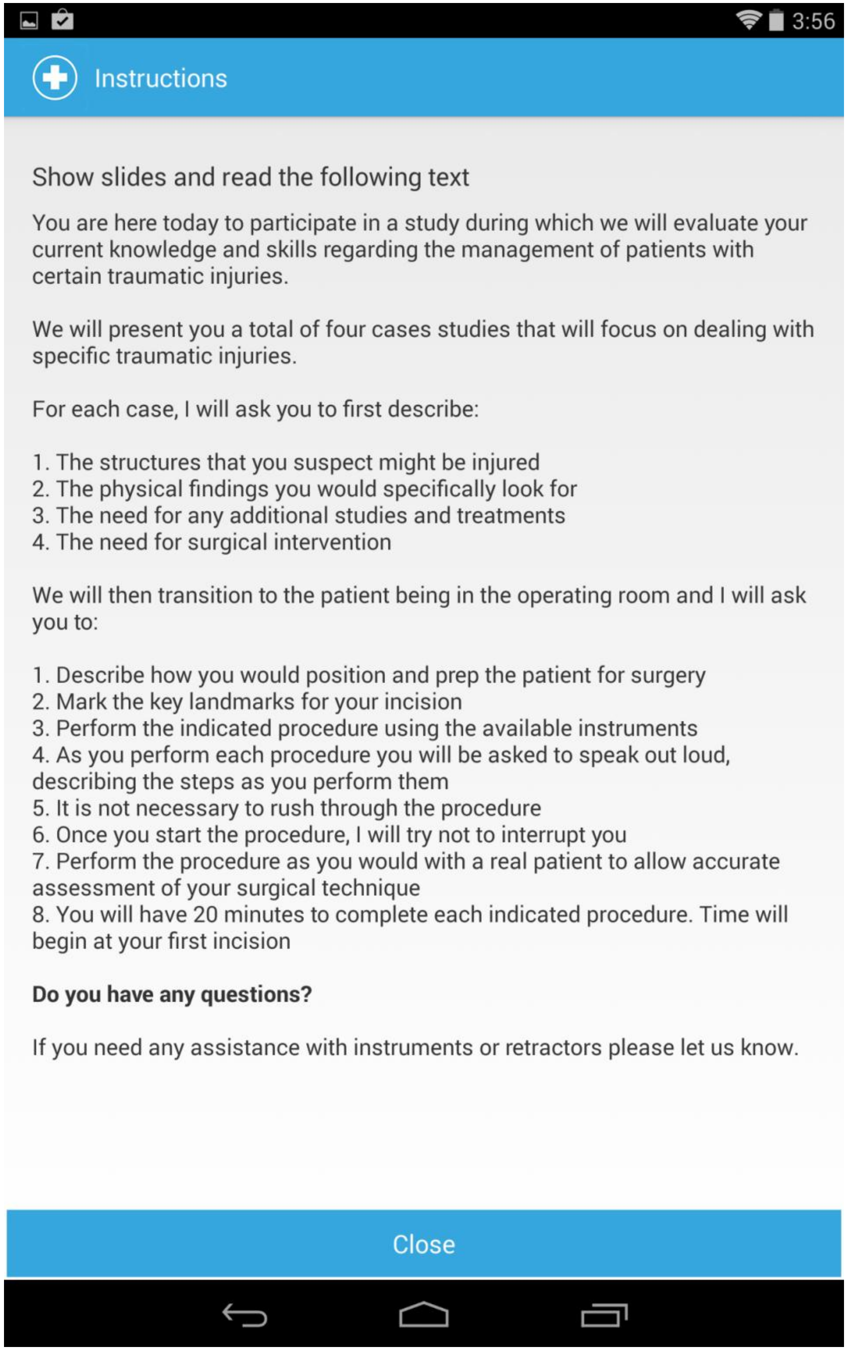
Exposure of major vasculature in the shoulder region:	1	2	3	4	5
Exposure of major vasculature in the arm:	1	2	3	4	5
Exposure of major vasculature in the forearm:	1	2	3	4	5
Exposure of major vasculature in the inguinal region:	1	2	3	4	5
Performance of a lower extremity fasciotomy:	1	2	3	4	5

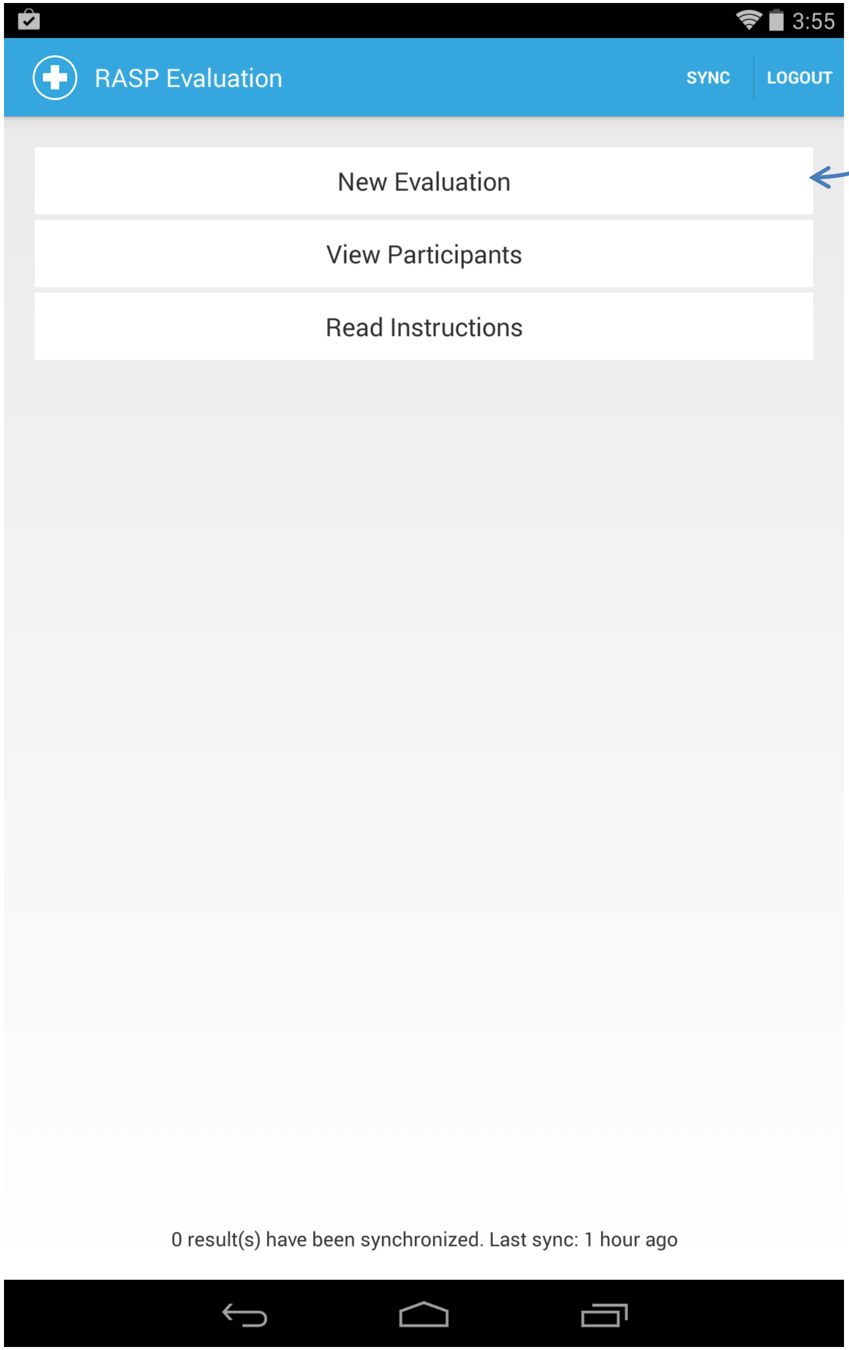
Participant Surgical Experience with Trauma Patients

		Residents
Trauma Patients Evaluated	Low	30 to 100
	Moderate	120 to 200
	High	250 to 550
Upper Extremity Vascular Repairs	Low	0 to 1
	Moderate	2
	High	3 to 35
Lower Extremity Vascular Repairs	Low	0 to 1
	Moderate	2 to 5
	High	6 to 35
Fasciotomies	Low	0
	Moderate	1 to 2
	High	3 to 20

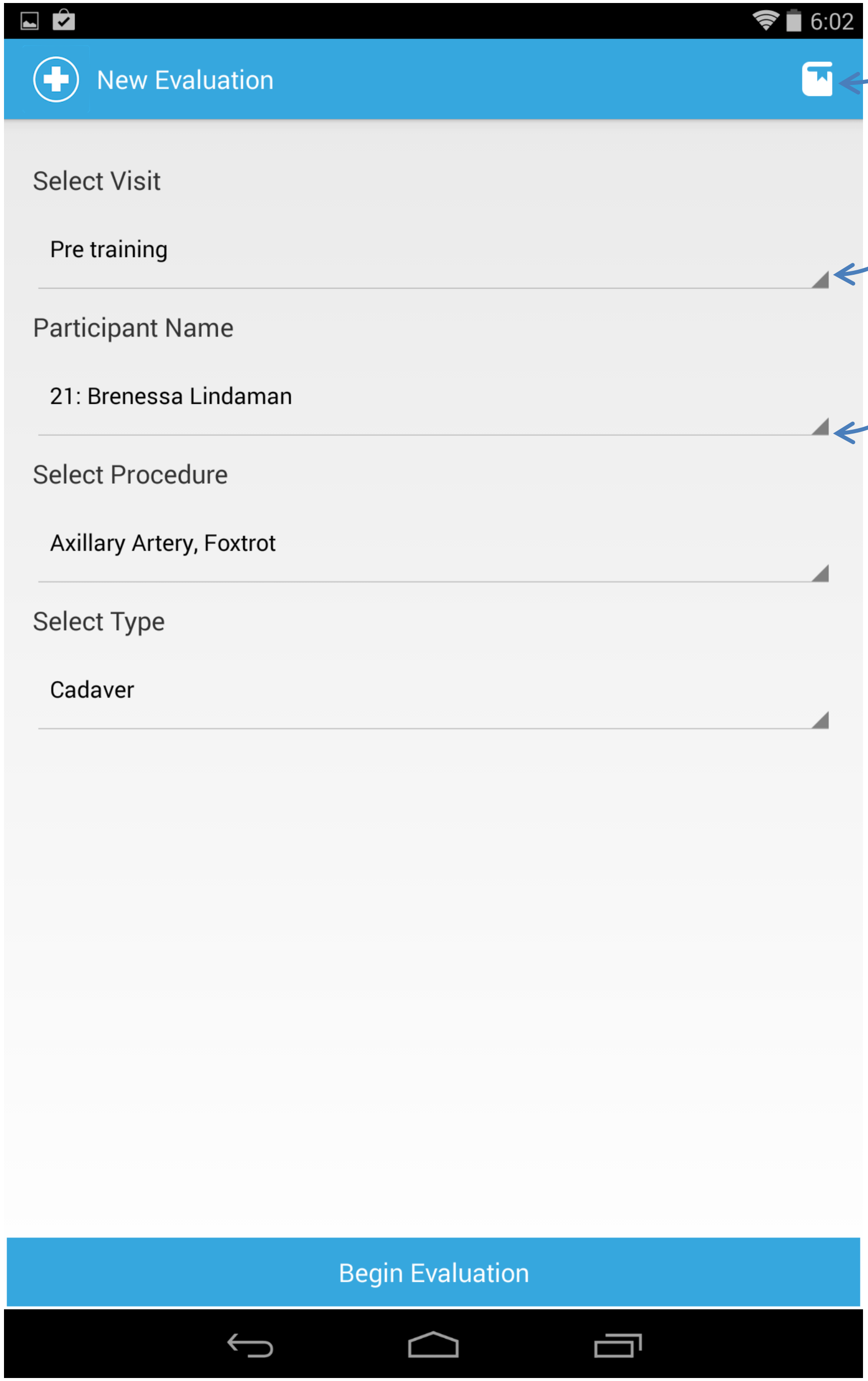


Script Reader:
Read RASP evaluation instructions to participant first


3:56
Instructions
Show slides and read the following text
You are here today to participate in a study during which we will evaluate your current knowledge and skills regarding the management of patients with certain traumatic injuries.
We will present you a total of four cases studies that will focus on dealing with specific traumatic injuries.
For each case, I will ask you to first describe:
1. The structures that you suspect might be injured
2. The physical findings you would specifically look for
3. The need for any additional studies and treatments
4. The need for surgical intervention
We will then transition to the patient being in the operating room and I will ask you to:
1. Describe how you would position and prep the patient for surgery
2. Mark the key landmarks for your incision
3. Perform the indicated procedure using the available instruments
4. As you perform each procedure you will be asked to speak out loud, describing the steps as you perform them
5. It is not necessary to rush through the procedure
6. Once you start the procedure, I will try not to interrupt you
7. Perform the procedure as you would with a real patient to allow accurate assessment of your surgical technique
8. You will have 20 minutes to complete each indicated procedure. Time will begin at your first incision
Do you have any questions?
If you need any assistance with instruments or retractors please let us know.
Close



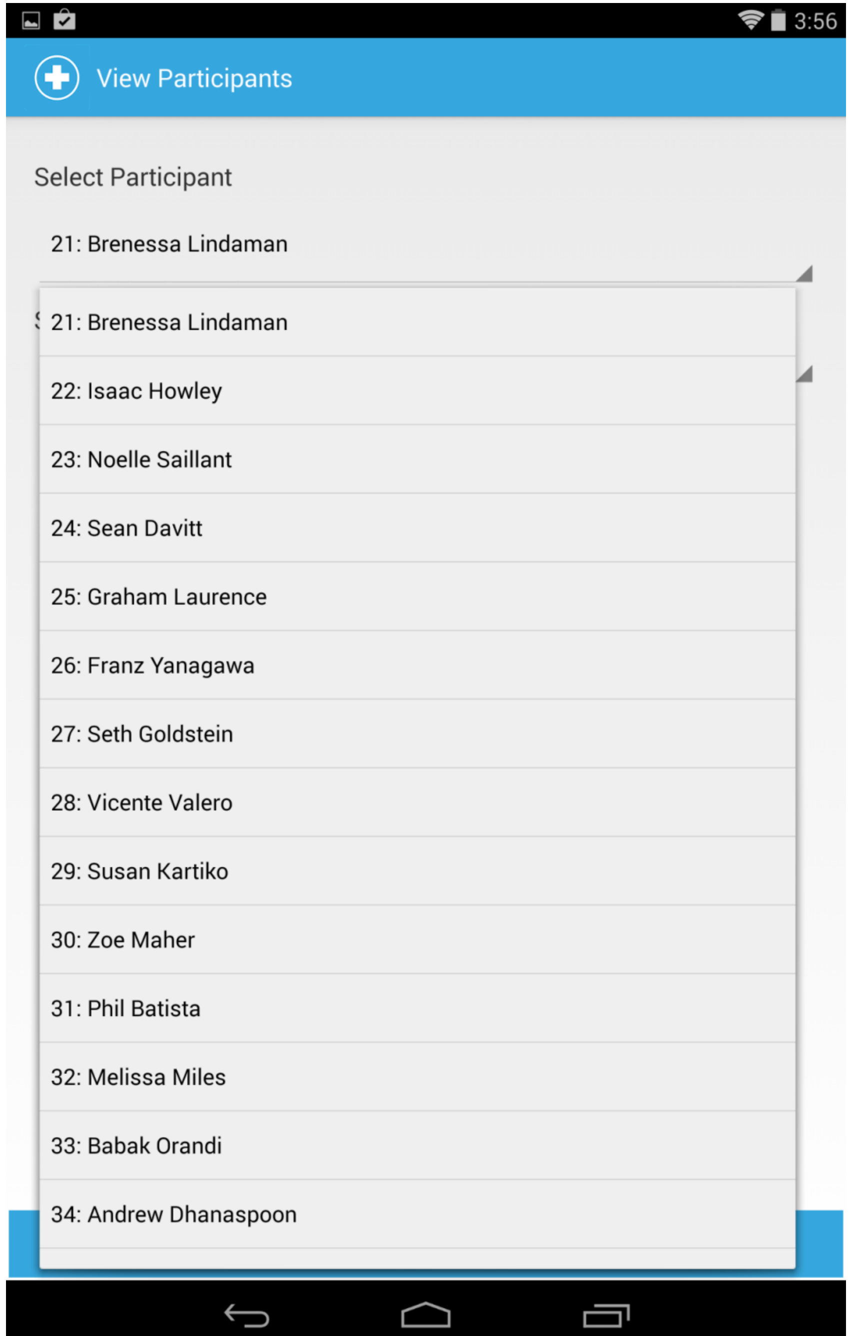
All e-team:
Select New Evaluation

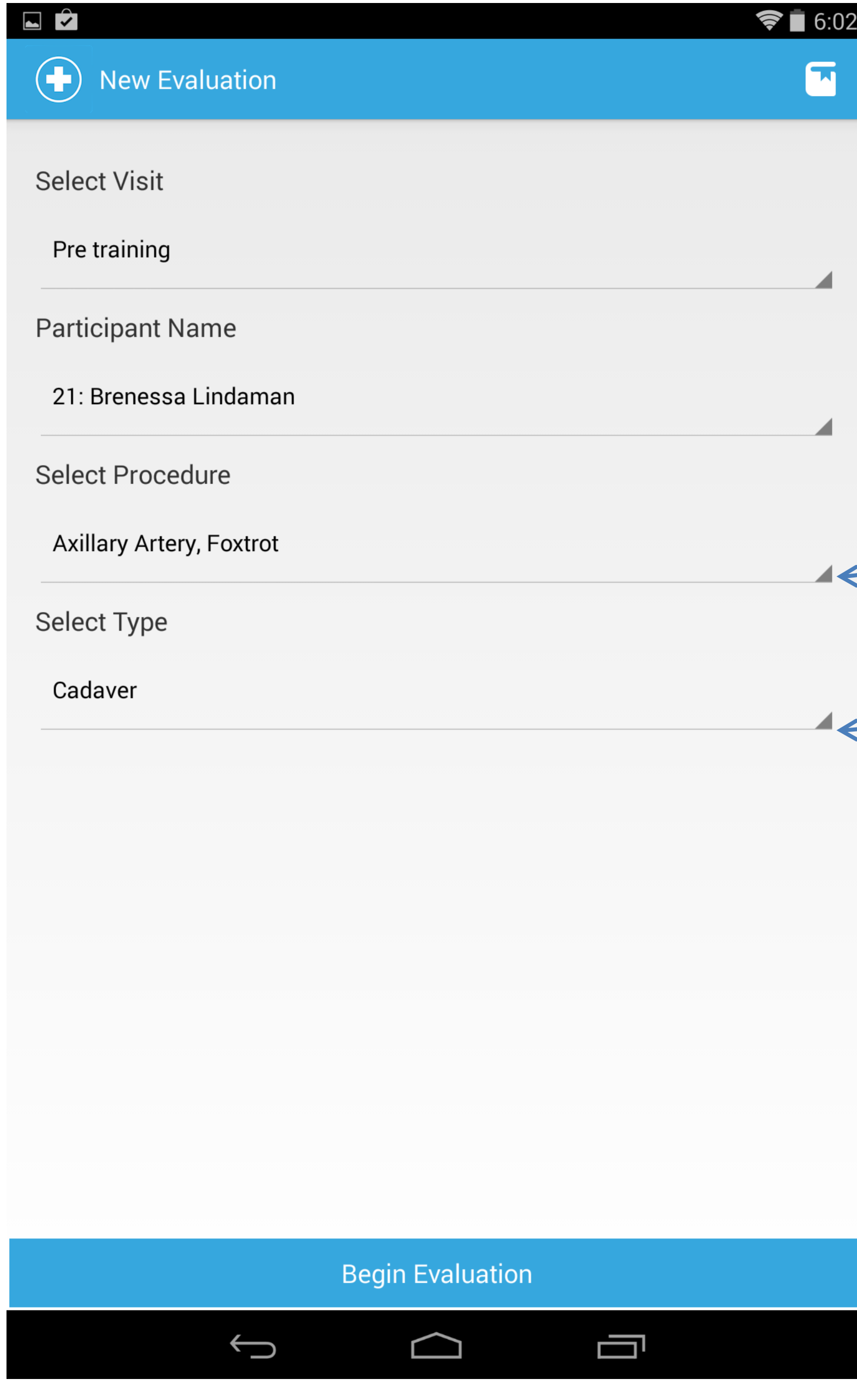


Can also get to evaluation instructions here!

Pre-ASSET training
Post-ASSET training
Retention

Select participant

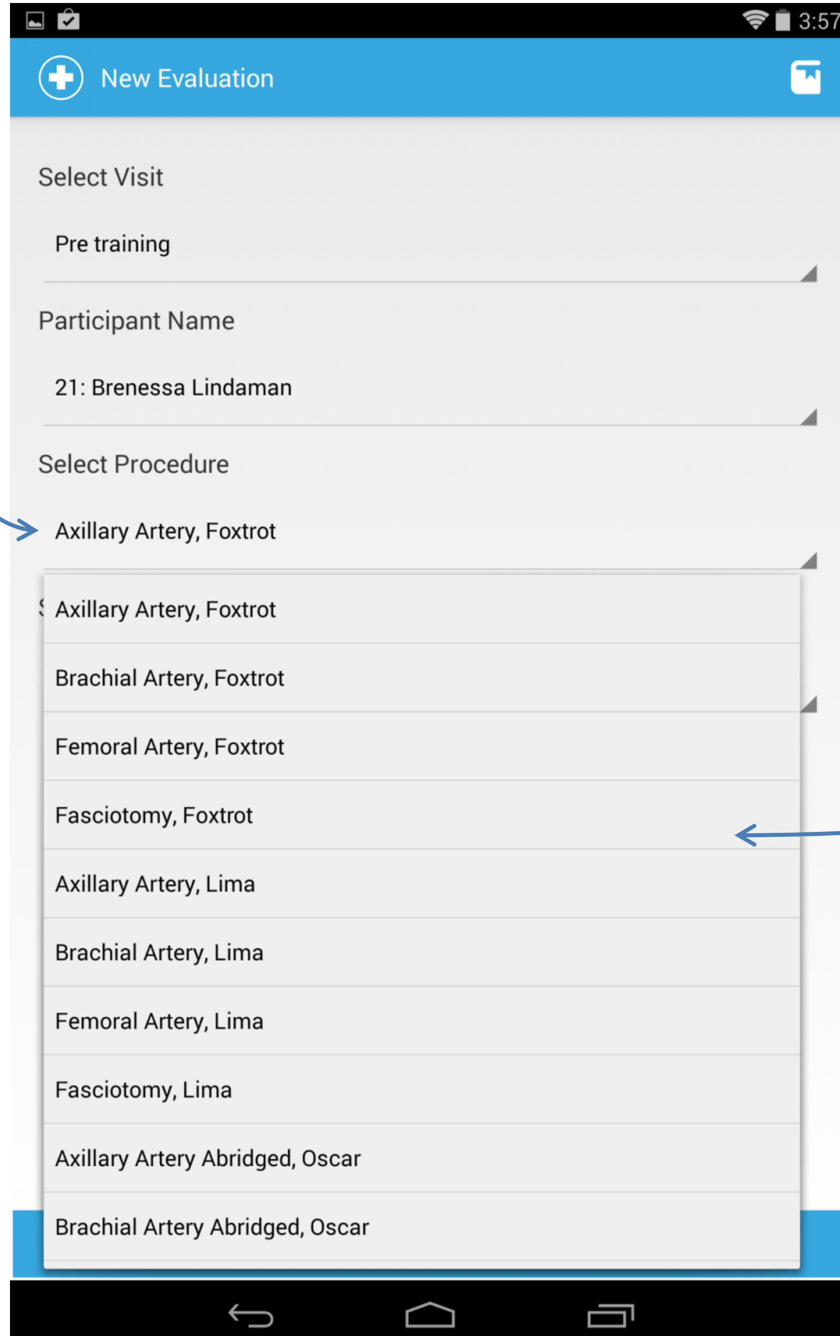

3:56
View Participants
Select Participant
21: Brenessa Lindaman
21: Brenessa Lindaman
22: Isaac Howley
23: Noelle Saillant
24: Sean Davitt
25: Graham Laurence
26: Franz Yanagawa
27: Seth Goldstein
28: Vicente Valero
29: Susan Kartiko
30: Zoe Maher
31: Phil Batista
32: Melissa Miles
33: Babak Orandi
34: Andrew Dhanaspoon



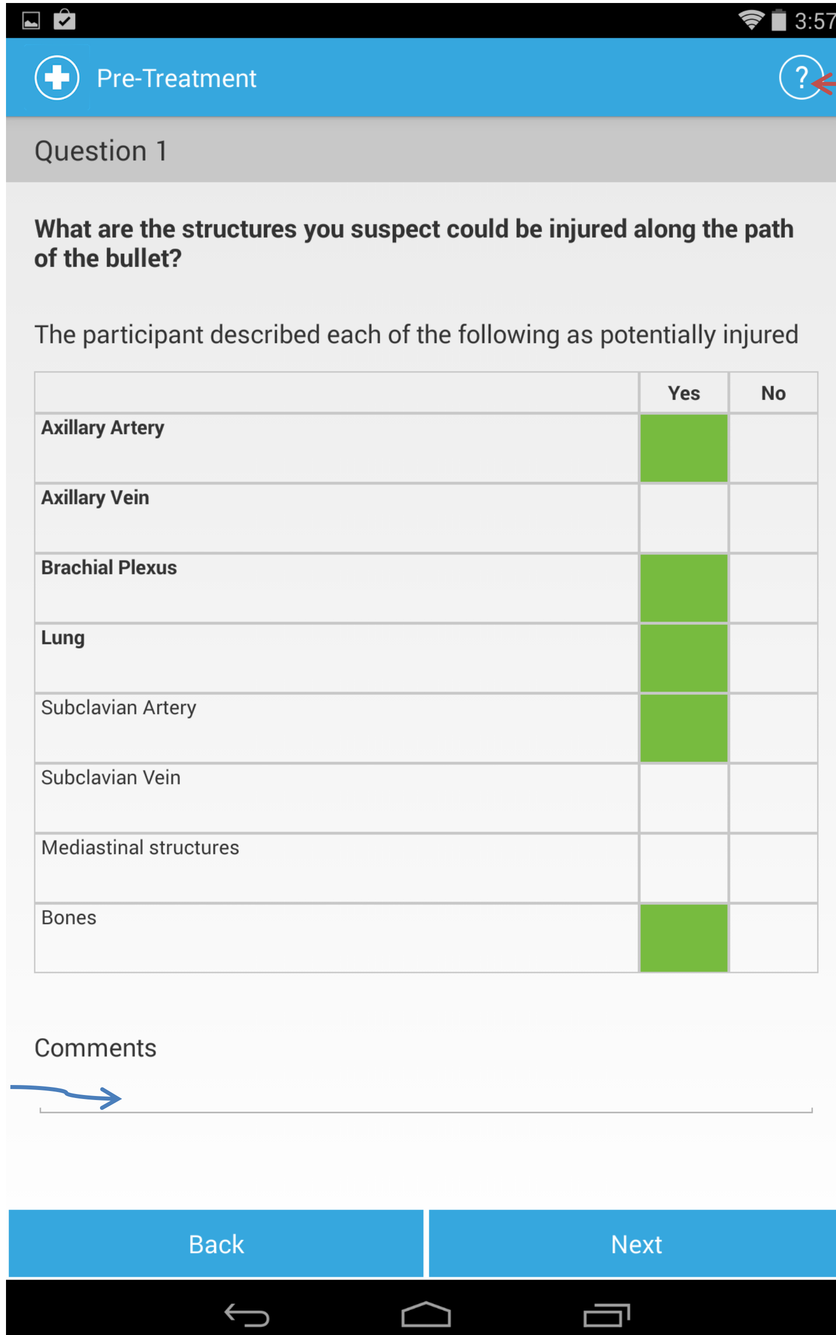
Select:
Procedure Script, Trial

Cadaver
Model

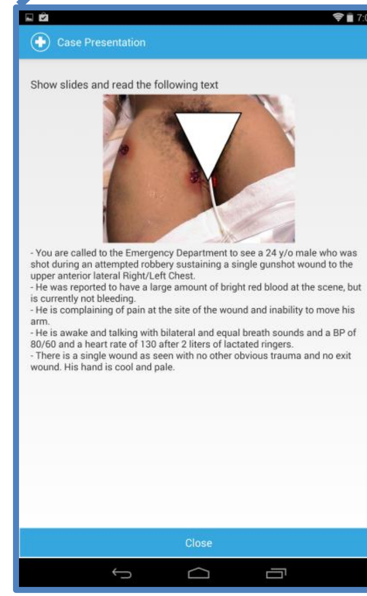
Select:
Procedure Script, Trial



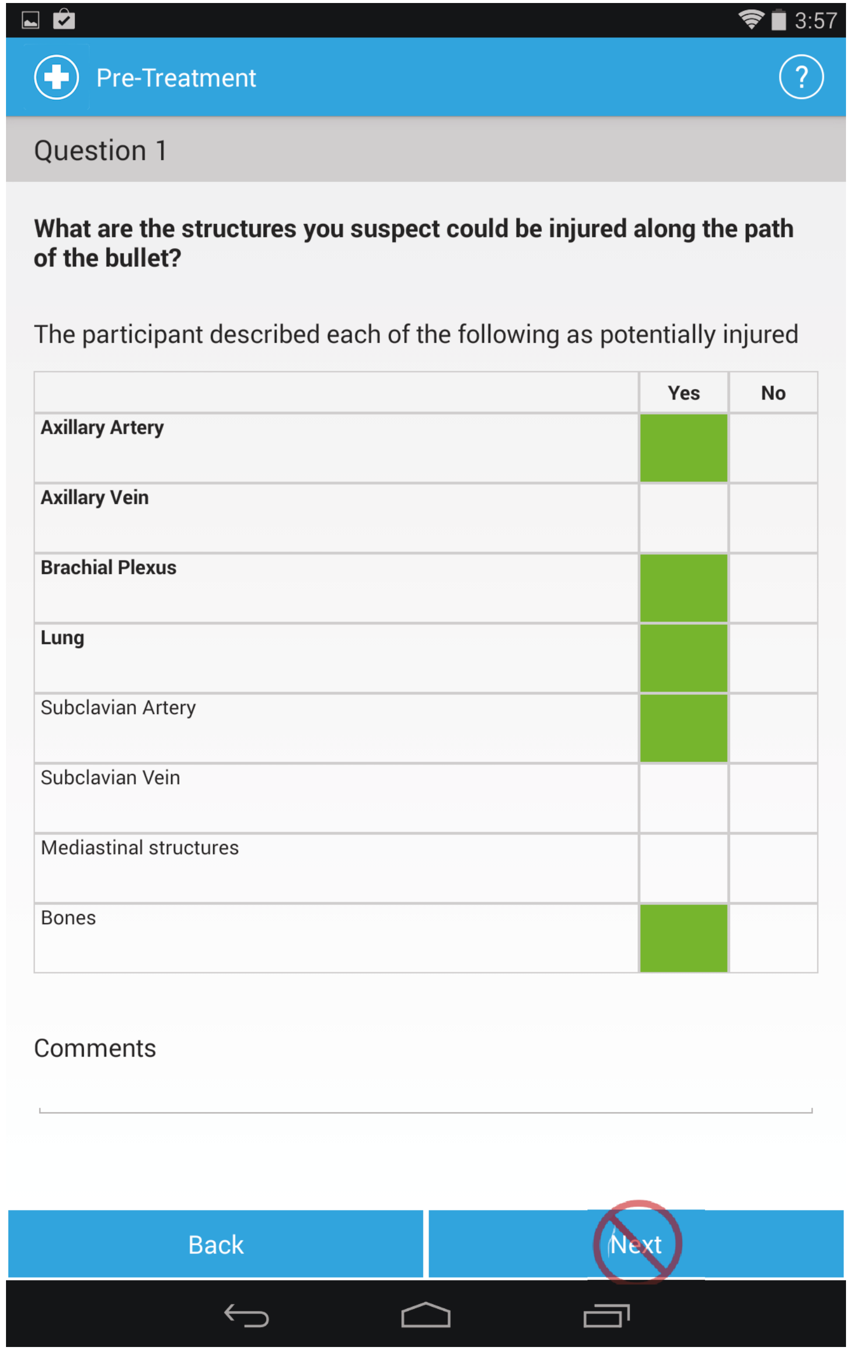
You will have printed instructions for which of these scripts and in what order you should select for each participant



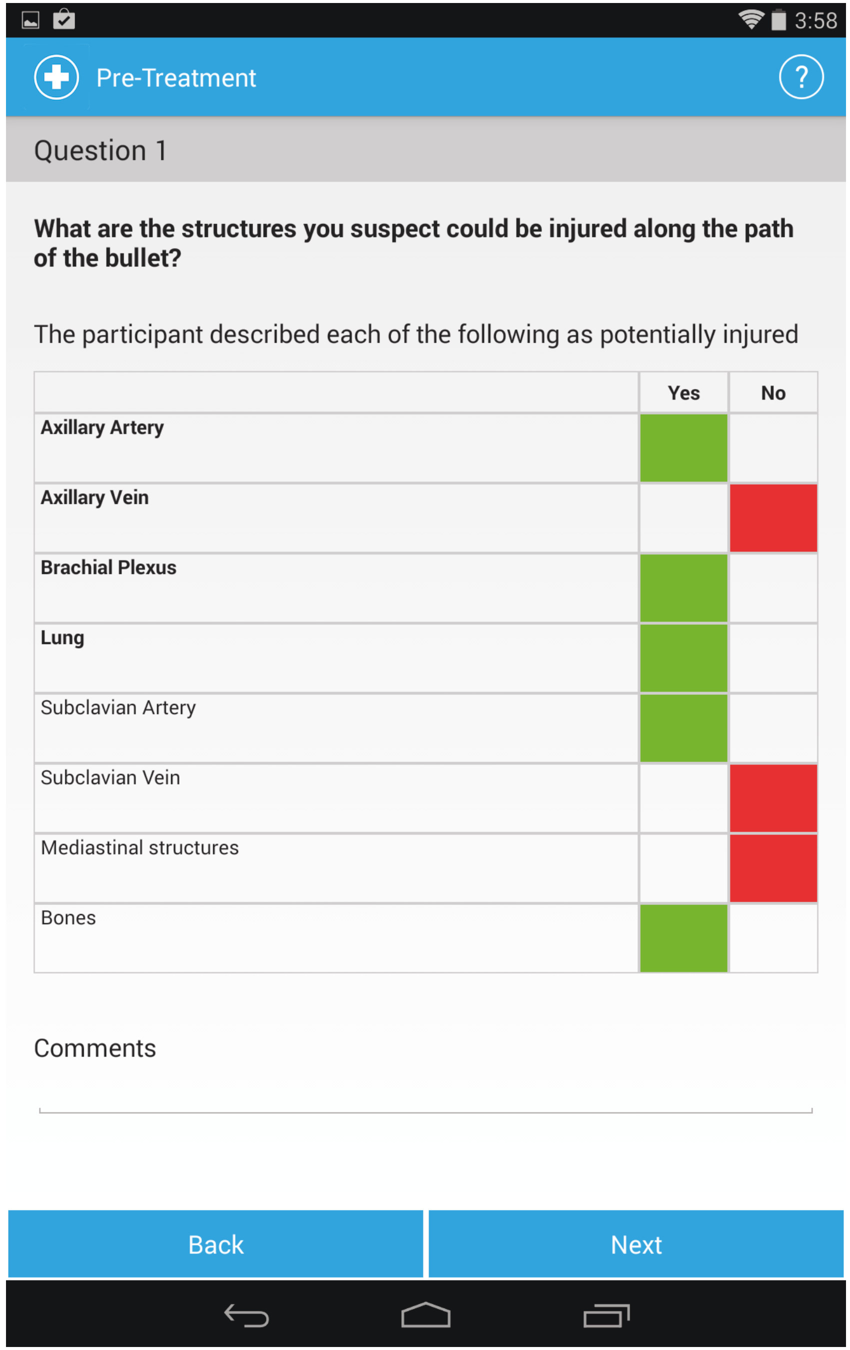
Touch here for Case Description



Type your initials into the first comments box, please!



Must fill all options before clicking NEXT



Now touch NEXT

3:59

Pre-Treatment

The patient's blood pressure is 85/65 and HR 110 and is unable to move his arm, has decreased sensation and absent brachial, radial, and ulnar pulses.

What additional studies would you perform to help you identify or rule out specific injuries in this patient?

The participant described each of the following as additional studies

	Yes	No
FAST exam to look for pericardial tamponade, hemothorax, pneumothorax		
Chest X-ray		
A marker (eg. paperclip) is placed to mark wound prior to x-ray		
CT of Chest		
CT of Angiogram		
Angiogram		

Errors

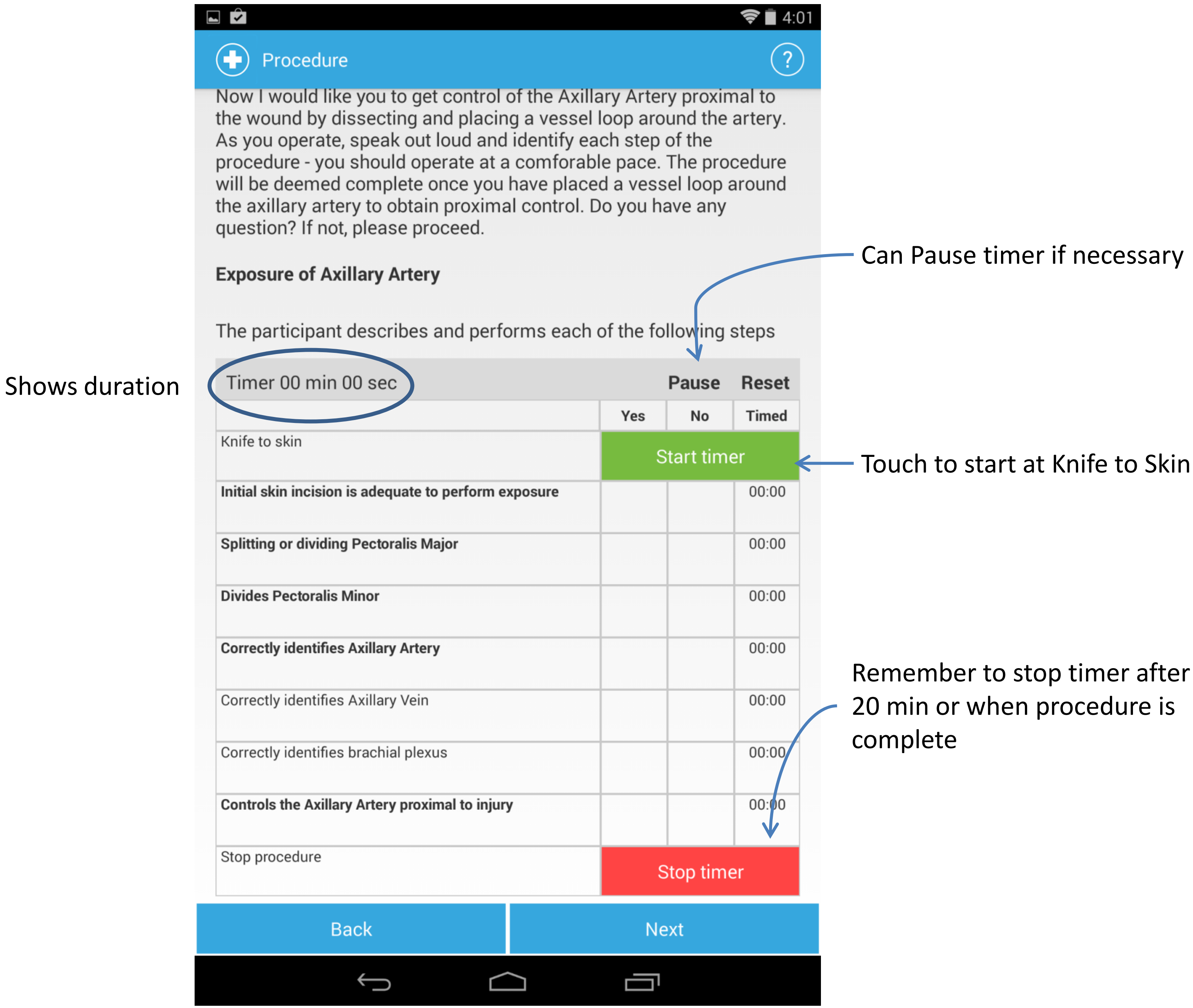
Fails to obtain CXR	
Innapropriate use of CT and Angio*	

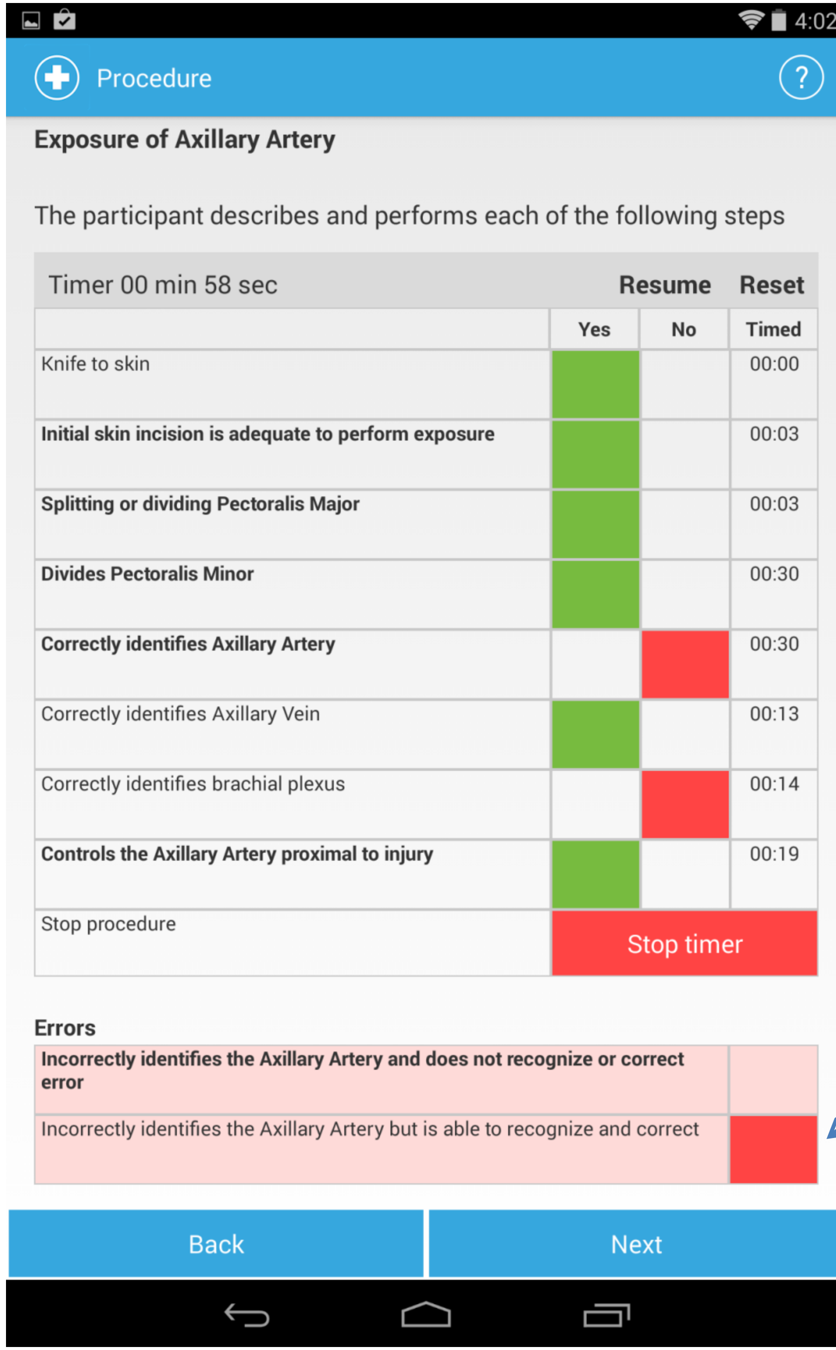
*All of the above tests are acceptable possible studies but the participant should clearly indicate these tests should only be done in a hemodynamically stable patient. Without this qualifier, performing any of these tests prior to taking this patient to the OR has potential for negative outcome and should result in negative value scoring.

Back | Next

Error Options: Can only select an error if the related answer is selected

Error Options: Can only select an error if the related answer is selected


4:01
Procedure
Now I would like you to get control of the Axillary Artery proximal to the wound by dissecting and placing a vessel loop around the artery. As you operate, speak out loud and identify each step of the procedure - you should operate at a comforable pace. The procedure will be deemed complete once you have placed a vessel loop around the axillary artery to obtain proximal control. Do you have any question? If not, please proceed.
Exposure of Axillary Artery
The participant describes and performs each of the following steps
Timer 00 min 00 sec
Pause
Reset
Yes
No
Timed
Knife to skin
Start timer
Initial skin incision is adequate to perform exposure
00:00
Splitting or dividing Pectoralis Major
00:00
Divides Pectoralis Minor
00:00
Correctly identifies Axillary Artery
00:00
Correctly identifies Axillary Vein
00:00
Correctly identifies brachial plexus
00:00
Controls the Axillary Artery proximal to injury
00:00
Stop procedure
Stop timer
Back
Next
Shows duration
Can Pause timer if necessary
Touch to start at Knife to Skin
Remember to stop timer after 20 min or when procedure is complete



4:02

Procedure

Exposure of Axillary Artery

The participant describes and performs each of the following steps

Timer 00 min 58 sec **Resume** **Reset**

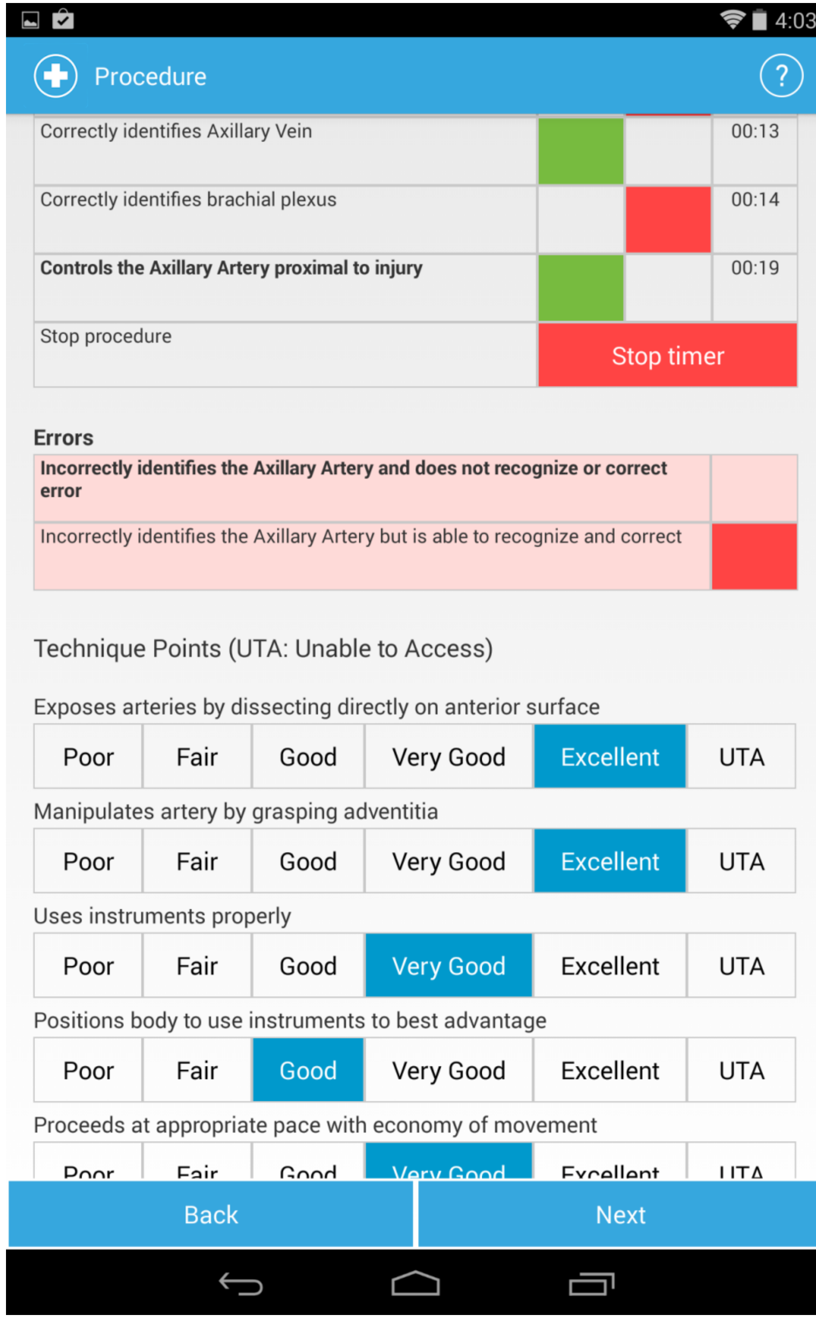
	Yes	No	Timed
Knife to skin			00:00
Initial skin incision is adequate to perform exposure			00:03
Splitting or dividing Pectoralis Major			00:03
Divides Pectoralis Minor			00:30
Correctly identifies Axillary Artery			00:30
Correctly identifies Axillary Vein			00:13
Correctly identifies brachial plexus			00:14
Controls the Axillary Artery proximal to injury			00:19
Stop procedure	Stop timer		

Errors

Incorrectly identifies the Axillary Artery and does not recognize or correct error	
Incorrectly identifies the Axillary Artery but is able to recognize and correct	

Back Next

Error Options: Can only select an error if the related answer is selected

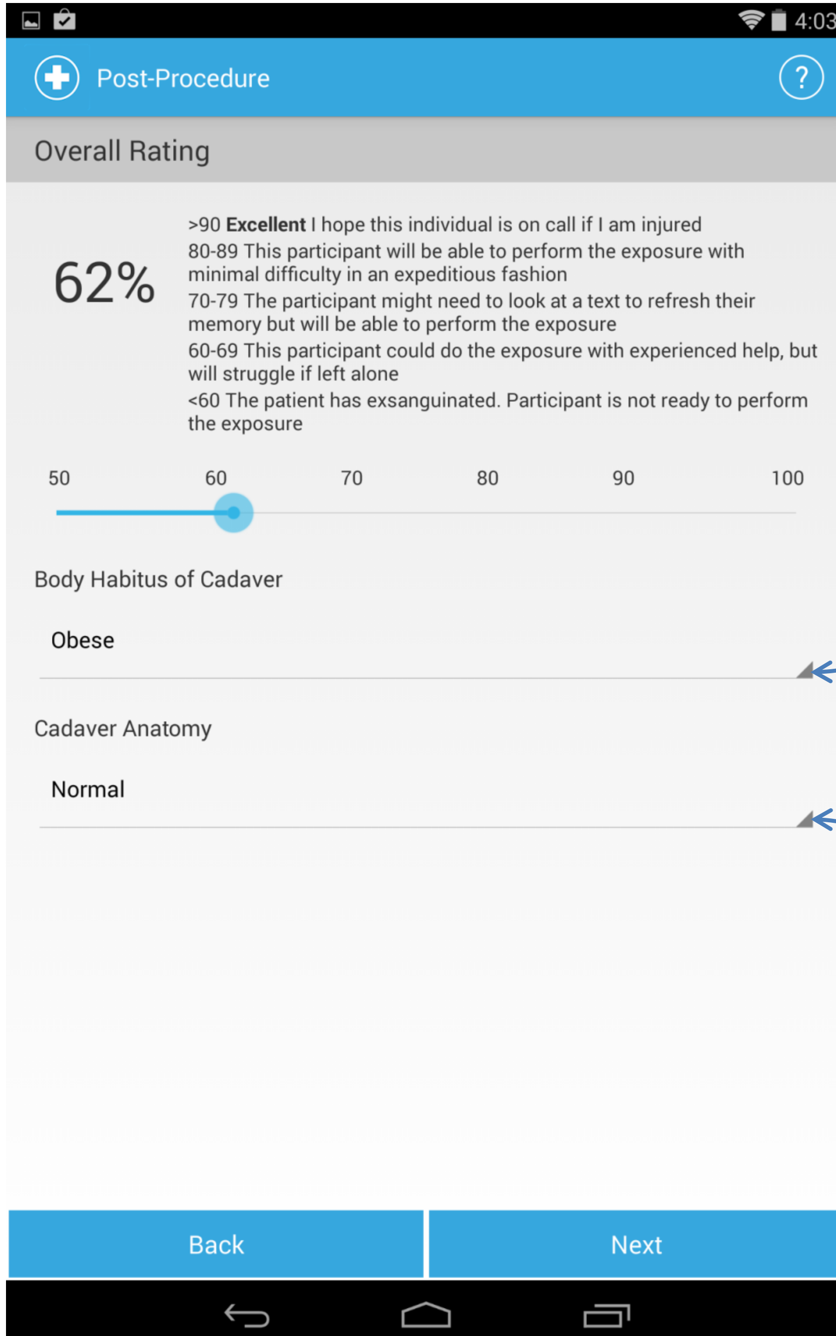


Only page where you can advance before all fields are completed.

Use to complete Discriminatory Criteria

Navigate between this page and Procedure

Evaluate Overall Knowledge & Technical skill here

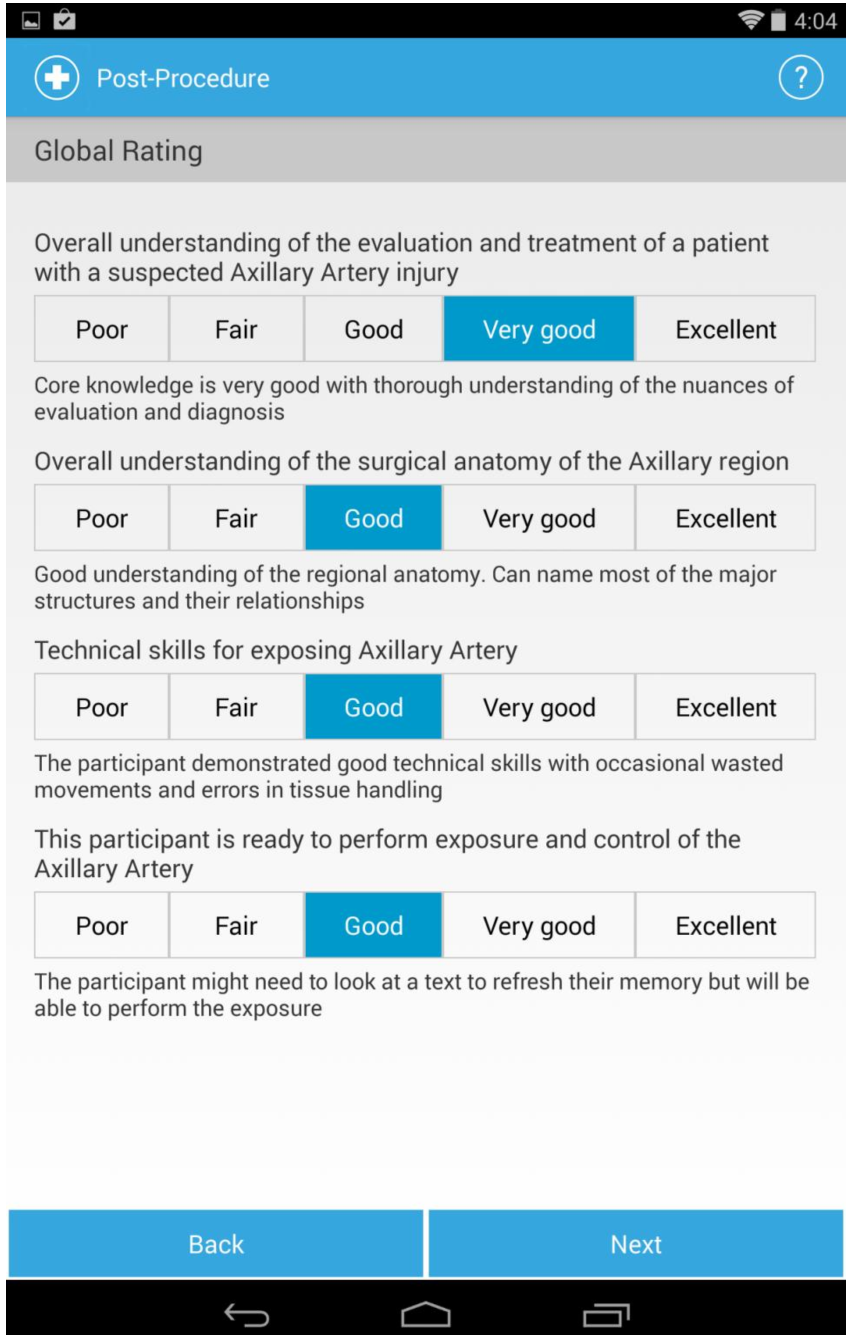


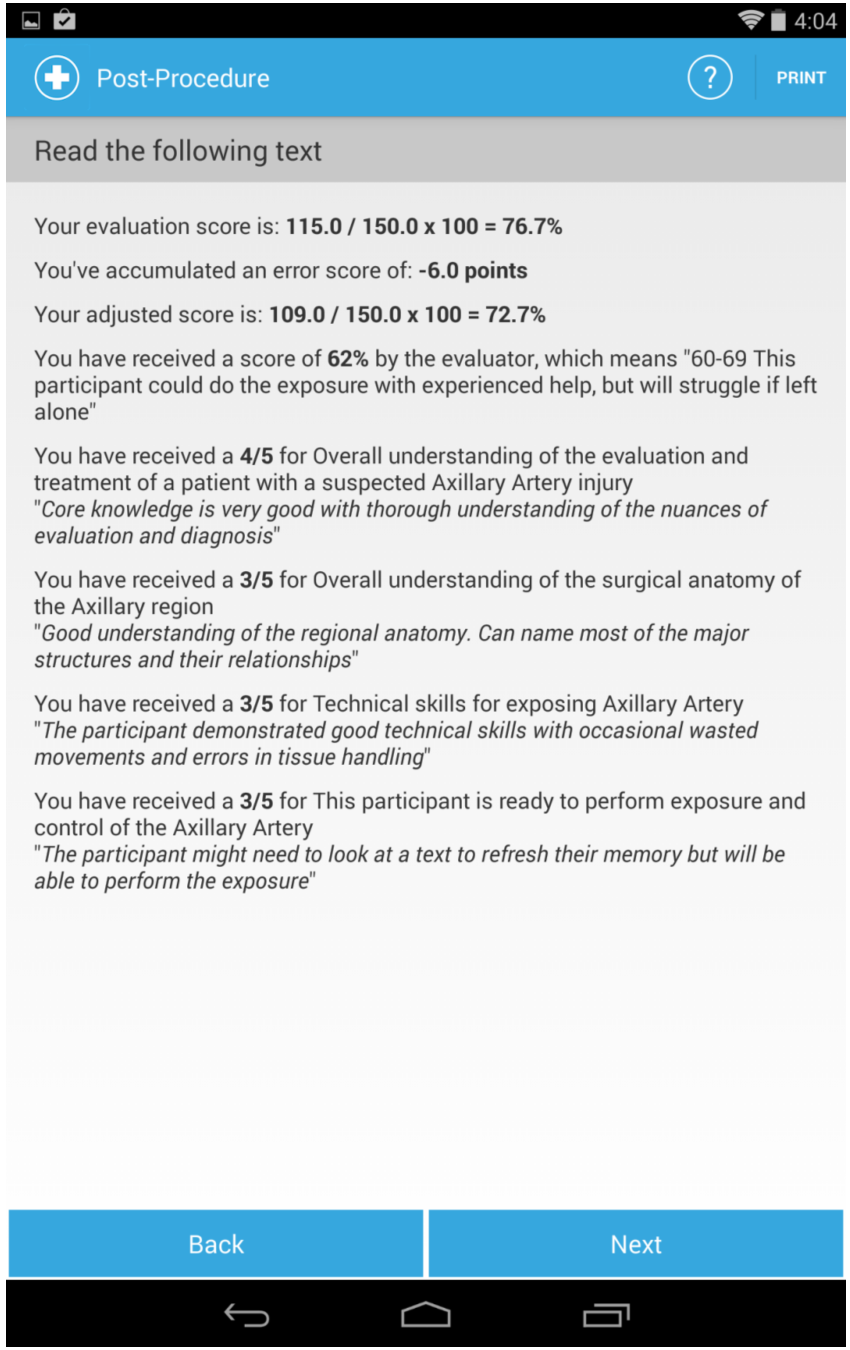
If performed on a cadaver, Select:

Cadaver Body Habitus
Obese
Average
Thin

Cadaver Anatomy
Normal
Variant

Global ratings for:
Knowledge, Technical skill &
Readiness here

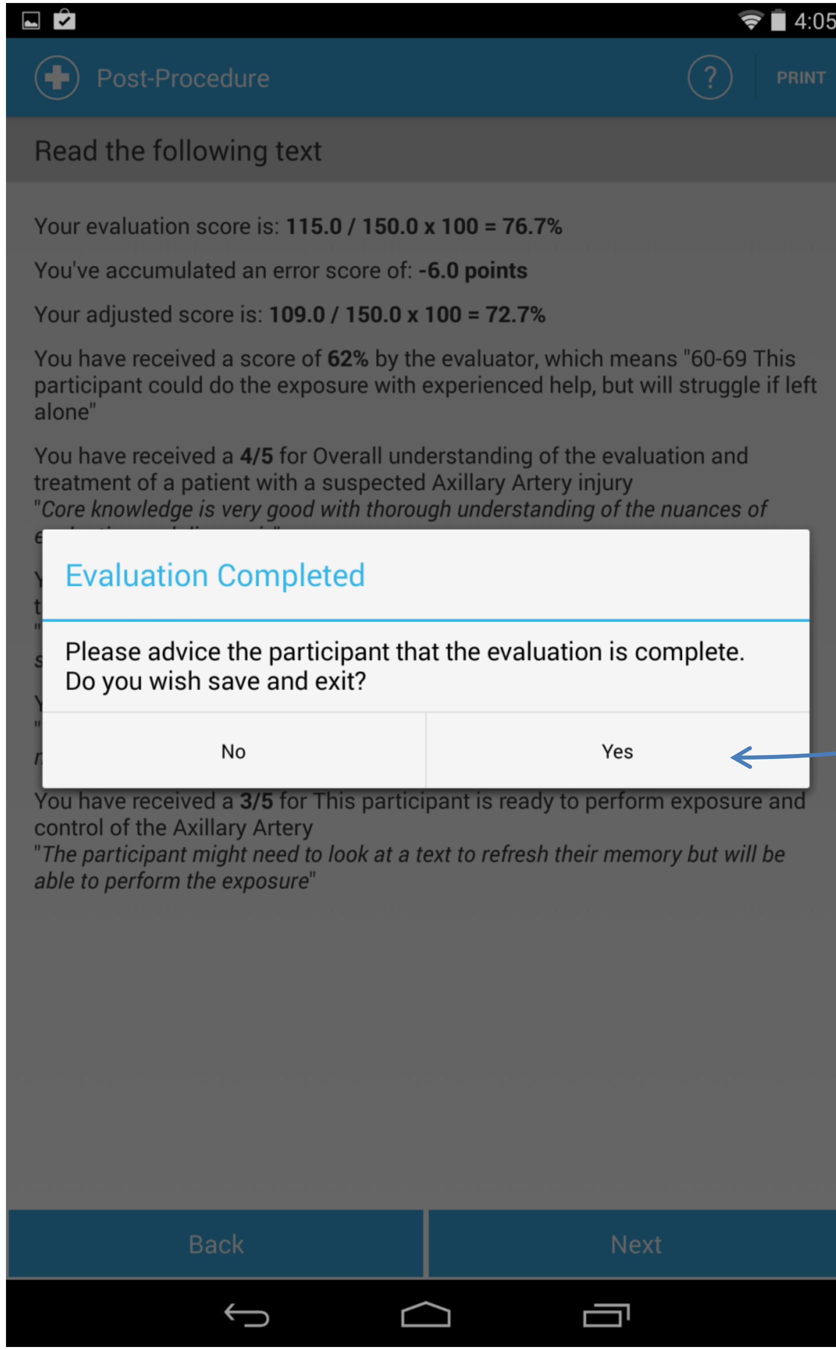




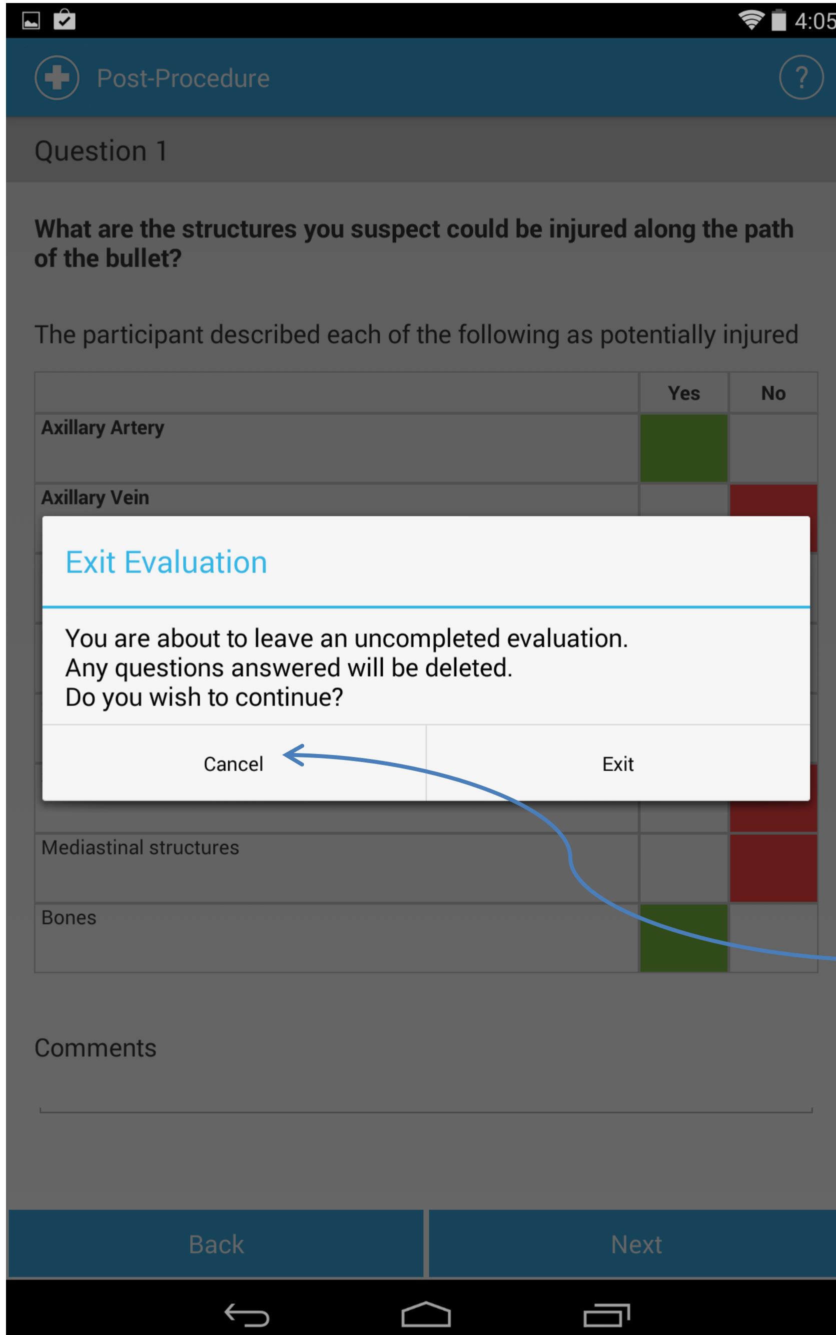
Score report will be available after each procedure is complete.

Please wait to de-brief until all four procedures are complete.

Instructions for viewing results to follow.



Finish and Save!



Hit BACK too many times, this happens.

If you touch EXIT, evaluation will be lost.

Don't do that.

4:09

Pre-Treatment

Question 4

What are the physical findings and symptoms that indicate a diagnosis of compartment syndrome in the lower leg?

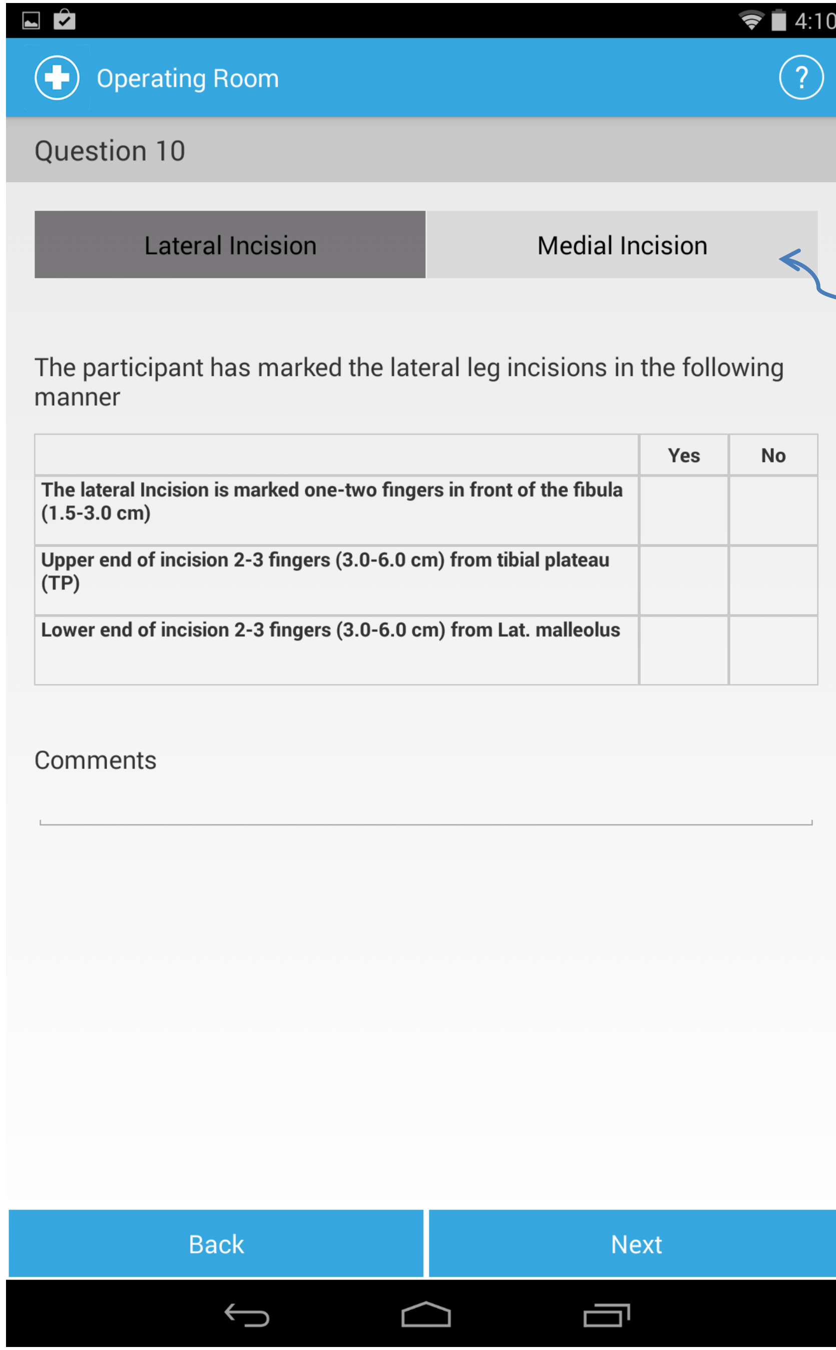
The participant describes each of the following

	Yes	No
Relates concept that one should have a low index of suspicion for making Dx		
The 5 P's: Pain		
The 5 P's: Parasthesias		
The 5 P's: Pallor/Pokilothermia		
The 5 P's: Pulselessness		
The 5 P's: Paralysis		
Limb may feel tense or hard		
States that waiting for the 5 P's to occur is waiting too long		

Comments

Back Next

Script alteration: need to select each P separately – software structure limitation



Navigate between Medial and Lateral Tabs

Can advance without filling all fields in both tabs.

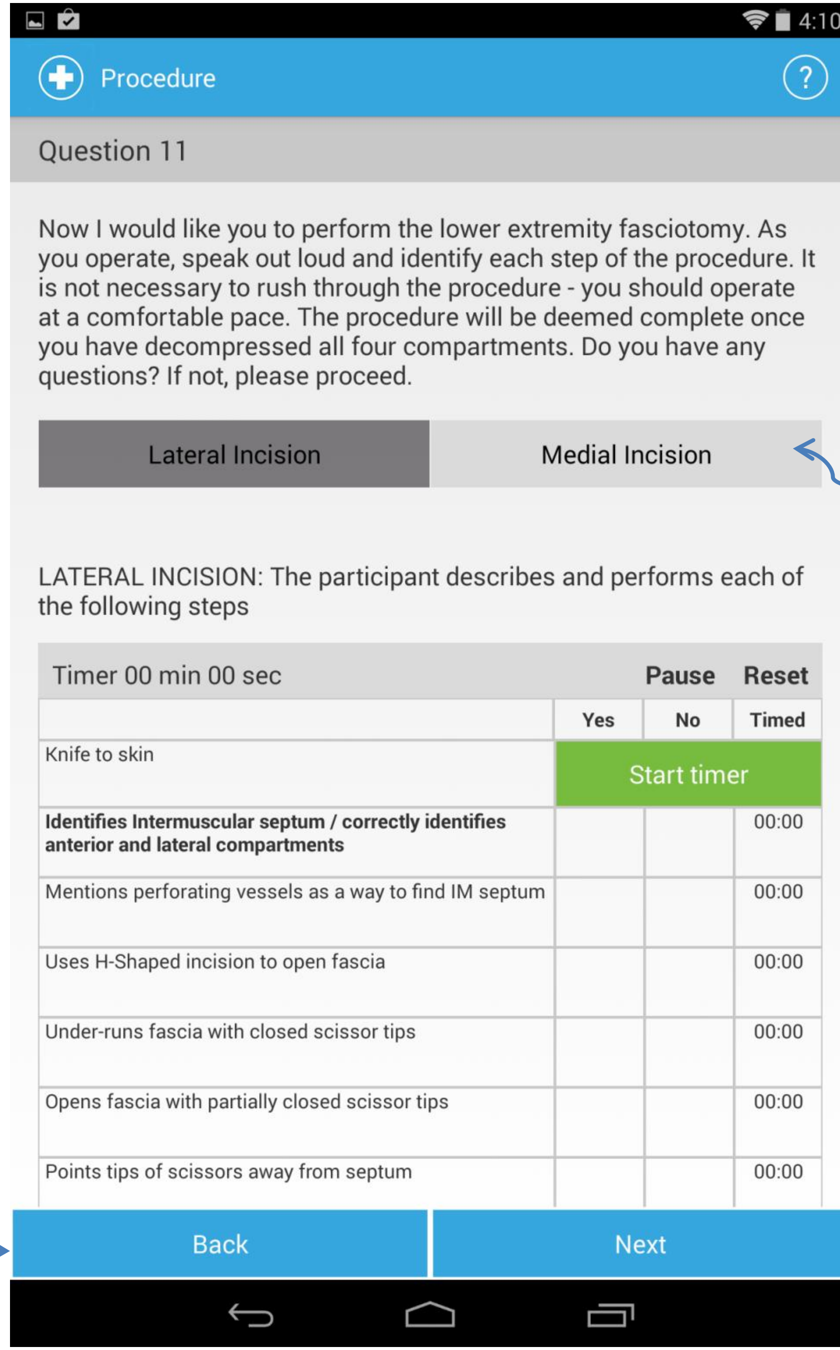
But have participant mark both sides before proceeding to the procedure

Navigate between Medial and Lateral Tabs

Can advance without filling all fields in both tabs.

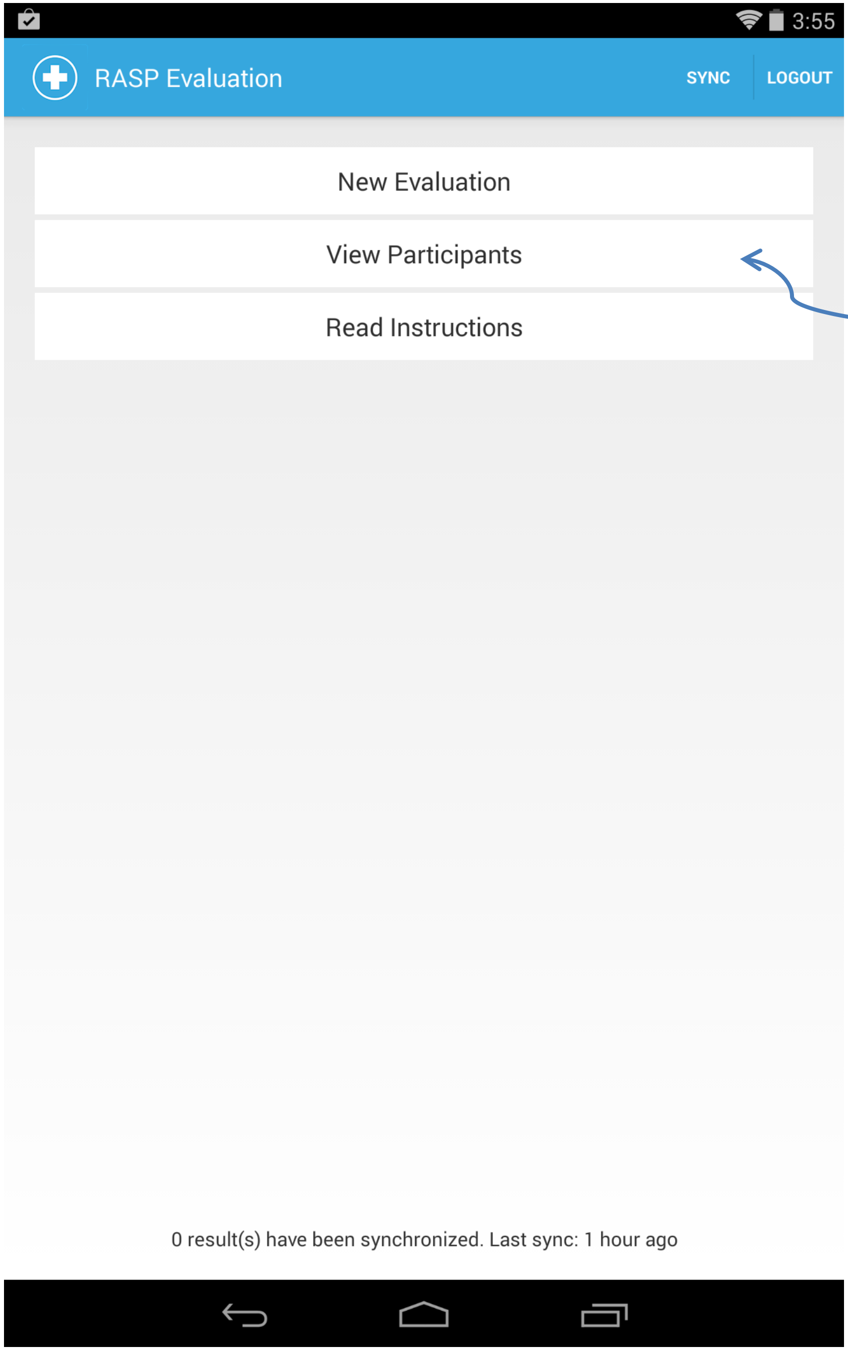
But have participant "complete" one side before proceeding to the next

Must start and stop timer for each Incision Tab!

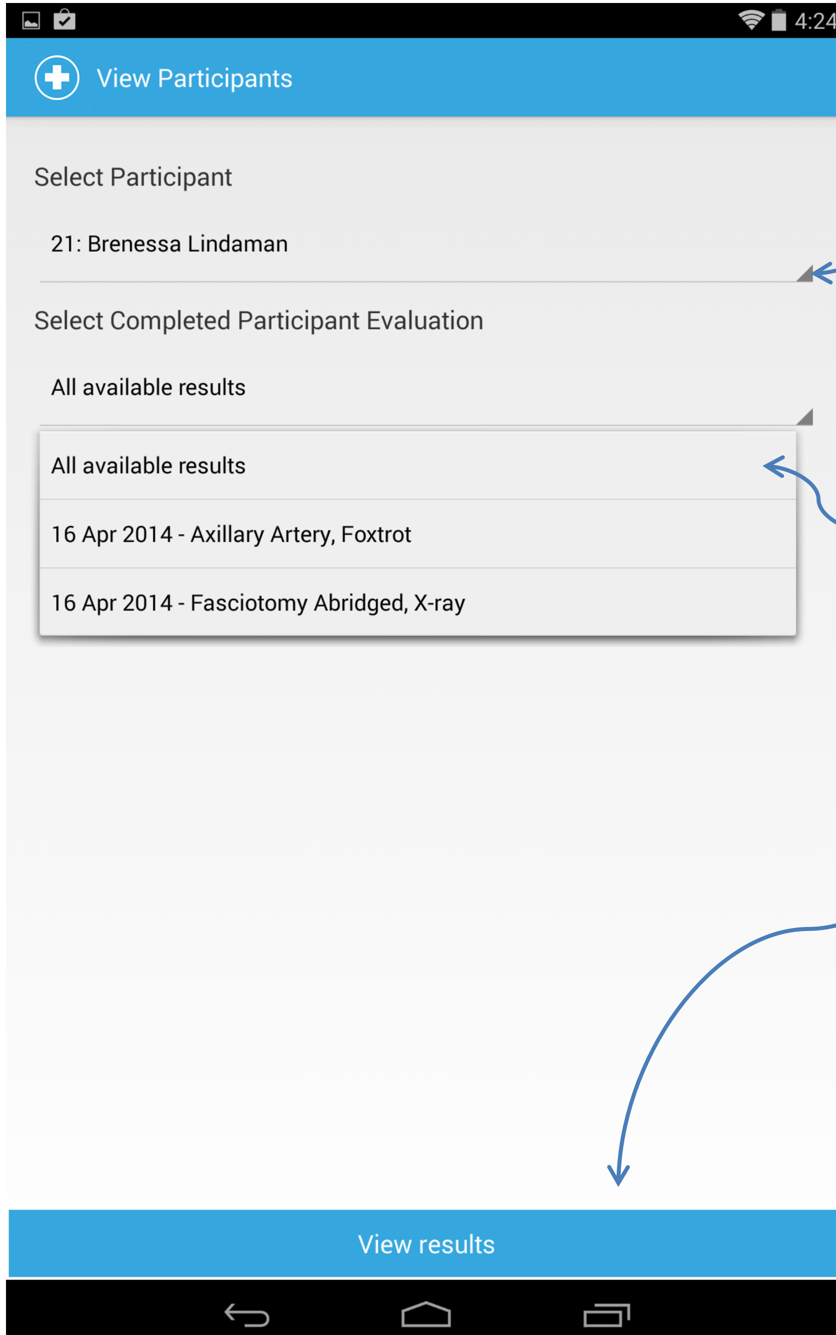


Navigate freely to Technique Points

Same Technique Points for both tabs.



To see all evaluation reports for your participant for de-briefing



Select participant

Select All Available Results

Or a specific procedure

Then touch here

Voilà:
Results for all saved evaluations will appear

4:24

Brenessa Lindaman Results

PRINT

16 Apr 2014 - Axillary Artery, Foxtrot

Case model type: **cadaver**

Body habitus of cadaver: **obese**

Cadaver anatomy: **normal**

Your evaluation score is: **117.0 / 150.0 x 100 = 78.0%**

You've accumulated an error score of: **-4.0 points**

Your adjusted score is: **113.0 / 150.0 x 100 = 75.3%**

Evaluator Ratings

You have received a score of **65%** which means "*60-69 This participant could do the exposure with experienced help, but will struggle if left alone*"

You have received a **3/5** for Overall understanding of the evaluation and treatment of a patient with a suspected Axillary Artery injury
"*Core knowledge is good with moderate understanding of nuances of evaluation and diagnosis*"

You have received a **3/5** for Overall understanding of the surgical anatomy of the Axillary region
"*Good understanding of the regional anatomy. Can name most of the major structures and their relationships*"

You have received a **3/5** for Technical skills for exposing Axillary Artery
"*The participant demonstrated good technical skills with occasional wasted movements and errors in tissue handling*"

You have received a **3/5** for This participant is ready to perform exposure and control of the Axillary Artery
"*The participant might need to look at a text to refresh their memory but will be able to perform the exposure*"

16 Apr 2014 - Fasciotomy Abridged, X-ray

Case model type: **cadaver**

Body habitus of cadaver: **obese**

Cadaver anatomy: **normal**

Your evaluation score is: **59.0 / 104.0 x 100 = 56.7%**

You've accumulated an error score of: **-2.0 points**

Is the participant finished for the day??

Print all reports to hand to the participant at the completion of the visit

APPENDIX IX:

Additional Questions Raised by Thesis Studies?

Question 1: An important question raised by the studies conducted as part of this Thesis is: what is performance of the resident surgeons after ASSET training in comparison to expert trauma-centre practicing Consultant Surgeons?

Figure Appendix IX a :(Below): Using ‘nearest-neighbor ‘classifiers green circle (experts) red circle (post ASSET) blue circle (pre ASSET) procedural steps and landmarks performance is related in 48 surgeons. Red dots represent those 21 surgeons who were not different to experts after ASSET training. Red stars represent those 19 surgeons NOT meeting performance of expert cohort despite ASSET training (see below)

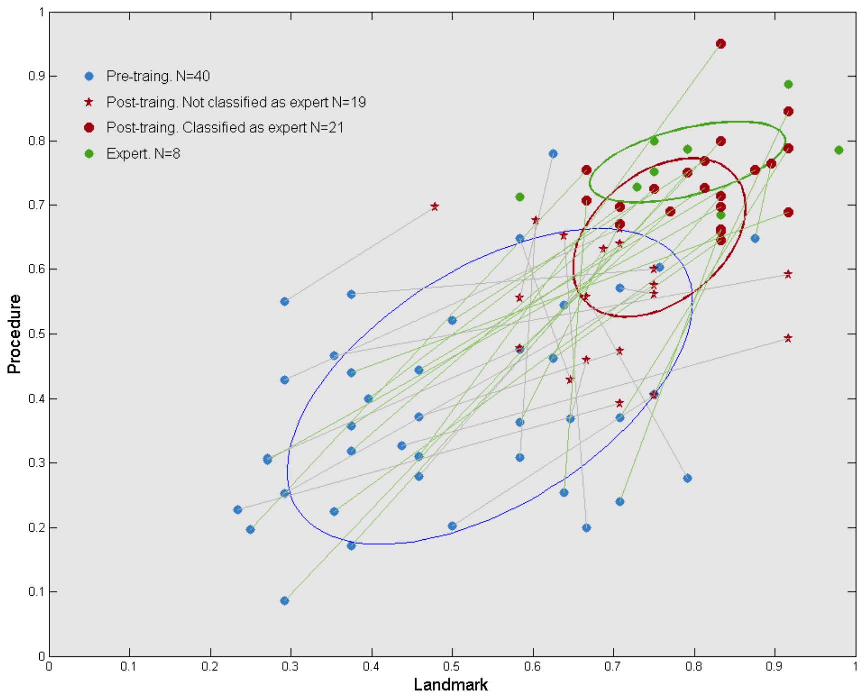


Figure Appendix IX a : Using nearest Neighbour classifiers in the Figure blue circled defines pre ASSET from the red circled Post ASSET surgeons and compare them to the green circled Experts when Correct Procedural Steps are plotted against Landmarks identification and skin incision placement, 21 surgeons shown as red circle are within this nearest neighbour classification of the experts after ASSET training. At the other end of the performance spectrum there are 19 of the post ASSET surgeons shown as red stars that do not leave the nearest neighbour of the blue circle indicating that ASSET Training did not improve their performance sufficiently to lift them out of an aggregated Pre-Training Cohort of performance

Do ASSET Skill Degrade?

A further question raised by the studies conducted as part of this Thesis is: When do skills taught on the ASSET Course degrade? See Fig 7.6 The answer is that they did not degrade for the 38/40 surgeon Group 2 cohort re-evaluated 12- 18 months (mean 1.2 years) after training.

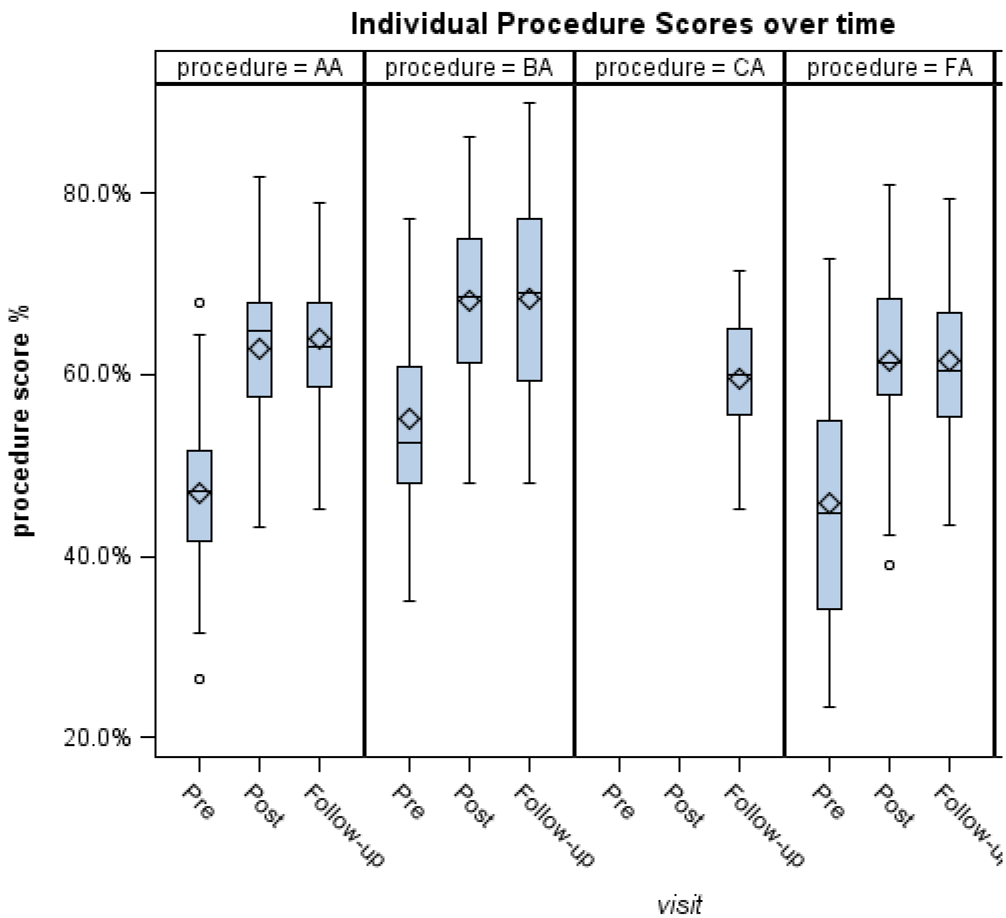


Figure Appendix IX b; shows the same surgeon cohort as were tested before and after ASSET training evaluated 12- 18 months after post- ASSET training evaluation. They in additional performed a “surprise” CA (carotid artery exposure) procedure that had been taught in the ASSET course, but these surgeons had not been previously evaluated on CA. The wide variability in performance as judged by IPS persists even 12- 18 months later