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Evidence-based Surgical Competency Outcomes from the Clinical Readiness Program

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MINI-ABSTRACT

This study examined the evidence provided through direct assessment of knowledge and procedural skills, and their association with the volume and diversity of surgical practice, to evaluate the strength of a competency framework designed to determine surgical capabilities in expeditionary contexts.

STRUCTURED ABSTRACT

Objectives: 1) Evaluate the value and strength of a competency framework for identifying and measuring performance requirements for expeditionary surgeons; 2) Verify psychometric integrity of assessment instrumentation for measuring domain knowledge and skills; 3) Identify gaps in knowledge and skills capabilities using assessment strategies; 4) Examine shared variance between knowledge and skills outcomes, and the volume and diversity of routine surgical practice.

Background: Expeditionary military surgeons provide care for patients with injuries that extend beyond the care requirements of their routine surgical practice. The readiness of these surgeons to independently provide accurate care in expeditionary contexts is important for casualty care in military and civilian situations. Identifying and closing performance gap areas are essential for assuring readiness.

Methods: We implemented evidence-based processes for identifying and measuring the essential performance competencies for expeditionary surgeons. All assessment instrumentation was rigorously examined for psychometric integrity. Performance outcomes were directly measured for expeditionary surgical knowledge and skills and gap areas were identified. Knowledge and skills assessment outcomes were compared, and also compared to the volume and diversity of routine surgical practice to determine shared variance.

Results: Outcomes confirmed the integrity of assessment instrumentation and identified significant performance gaps for knowledge and skills in the domain.

Conclusions: Identification of domain competencies and performance benchmarks, combined with best-practices in assessment instrumentation, provided a rigorous and defensible framework for quantifying domain competencies. By identifying and implementing strategies for closing performance gap areas, we provide a positive process for assuring surgical competency and clinical readiness.

INTRODUCTION

Military surgeons are tasked with caring for trauma victims that result from conflict, terrorism, or other mass casualty events, regardless of their specialty or sub-specialty training. That is, in expeditionary deployment contexts, it is equally likely that military sub-specialty surgeons (e.gs. bariatric, colorectal, pediatric, etc.) will be required to care for trauma victims as it is that trauma specialists to provide the necessary care. Consequently, military surgeons who are trained and maintain active surgical practices in other sub-specialty areas must also attain and maintain the ability to provide competent surgical care for trauma victims, often in complex and austere environments with limited resources. This challenge is amplified by the fact that military surgeons must attain and maintain these critical competencies across a broad base of surgical capabilities that are rarely, if ever, required during peacetime clinical practice.

There are significant challenges associated with attaining and maintaining these critical competencies prior to, and between, expeditionary deployments.[1-3] As a result, the Department of Defense (DoD) and the American College of Surgeons (ACS) initiated the Clinical Readiness Program (CRP), which is designed to assure the preparedness of military surgeons to provide maximum support across the entire spectrum of deployed or expeditionary operations. The CRP is comprised of four elements (knowledge assessment, skills assessment, training/retraining, and a surgical practice metric) that collectively form a program for Military Surgery – Maintenance of Expeditionary Currency and Competency (MS-MOC^2). The development of the MS-MOC^2 program is a multi-step process designed to be both scalable and reproducible across medical specialties.

The CRP assures individual surgical readiness by capturing representative performance data, comparing those performance data against pre-defined benchmarks, and providing focused resources to close any performance gaps. We defined clinical readiness as the integration of measurable knowledge, skills, and abilities (KSAs) to quantify the readiness competencies of expeditionary general surgeons.[4] The KSA framework supports a systematic approach to assessing readiness competencies against established benchmarks in key performance areas. These provide an evidence base for identifying gap areas where additional time, resources, or other support systems are required to achieve the performance requirements.[5-6] Apart from the expeditionary unique elements of the program, this work is applicable to all surgical specialties including surgical readiness for civilian mass casualty events, and rural and humanitarian practice. Our aim in this manuscript is to describe the initial readiness outcomes from the CRP for military general surgeons, and connect their relevance to both the future of military surgical readiness and civilian maintenance of certification.

METHODS

This study was reviewed and approved by the Institutional Review Board at our institution, and consisted of four primary components: 1) Characterize the performance requirements for the domain of expeditionary surgery; 2) Specify performance benchmarks for each

requirement; 3) Measure performance for each requirement; 4) Identify gap areas for training or re-training.

Performance Requirements for Expeditionary Surgeons

A panel of Army, Navy, and Air Force general surgeons, with relevant expertise and recent deployment experience, established the required competencies for expeditionary general surgeons.[7] The panel reviewed multiple specialty and military clinical practice guidelines that typify the performance requirements for the domain, and employed a consensus approach to identify 8 critical performance categories, 46 sub-categories, and 405 specific competencies (Table 1). These competencies were further divided into the dimensions of knowledge, skills, and abilities, and performance benchmarks were determined for each using an Angoff process.[8]

The performance benchmarks facilitated the development of assessment systems designed to measure knowledge and skills capabilities for each competency. We developed assessment instrumentation to capture performance data for both knowledge and skills competencies, with measurement accuracy and fairness paramount to our considerations. The resulting data include scores from a knowledge exam, and composite scores from multiple skills assessments associated with 30 expeditionary procedures. We examined the psychometric properties of all instrumentation to assure the accuracy of measurement and interpretation of performance outcomes.

Finally, we compared the assessment outcomes for both knowledge and skills with an abilities metric derived from pre-deployment practice to characterize clinical readiness.[9] The resulting analyses integrated data from the three competency dimensions (knowledge, skills, and abilities) to assure comprehensive characterization of clinical readiness for expeditionary general surgeons. This approach leveraged the power of data triangulation for measurement precision, psychometric integrity, accuracy, and fairness, which are essential for socialization and acceptance of these processes across military medicine.

Sample

We established validity evidence for assessment instrumentation by capturing data from two purposive samples of board-certified, active duty, military general surgeons for knowledge (N=238) and skills (N=104) competencies. Because surgical experience, prior training, and deployment history influence capabilities in expeditionary surgery, we also examined the influence of these variables on performance outcomes for validity confirmation. Sample characteristics for surgical specialty and sub-specialty are presented in Table 2, years of professional experience in Table 3, and deployment history in Table 4.

Knowledge Sample

A sample of 238 surgeons completed the knowledge assessment. Of the sub-specialties, critical care and trauma represented the largest group (29%). Deployment histories ranged

from no experience to greater than five years in both non-combat and combat zones. The average number of deployments for the sample was 3.45 (standard deviation=3.87). The most frequent duration of deployment was 1-3 months for non-combat zones and 4-6 months for combat zones.

Skills Sample

A sample of 104 surgeons without trauma surgery fellowship training, participated in the assessment of skills for 30 trauma procedures. The experience levels of the sample ranged from less than five years to greater than 20 years. The skills sample ranged from no deployment experience to multiple deployments to non-combat zones and combat zones.

Measurement of Expeditionary Surgeon Readiness

Assessment for both knowledge and skills dimensions focused on the performance of expeditionary domain-specific competencies, and instrumentation was designed to characterize the range of performances for each dimension. Instrumentation and measurement details for both knowledge and skills assessments are described below. To enhance internal validity of measurement, we assessed both knowledge (written exam) and skills (performance assessment) in structured environments. To enhance external validity, we compared the skills assessment outcomes with metric data that quantify the volume and variance of surgical performance within the contexts of routine surgical care during non-deployment. These data are calculated from clinical practice data that are adjusted to encourage the volume, diversity, and acuity (complexity) of procedures typically required in expeditionary environments.[10-12] These data were shared with this study for analyses; we did not directly measure these values.

Assessment of Expeditionary Surgical Knowledge

We created and examined the psychometric integrity of knowledge assessment instrumentation using a proctored online examination. The exam was comprised of 200 multiple choice questions distributed to capture the breadth and depth of expeditionary surgical practice. Content validity was confirmed by 25 subject matter experts and by the discriminant differentiation of outcomes by specialty and deployment history. Factor analysis confirmed measurement validity, and reliability was confirmed through Cronbach's alpha measure of internal consistency (>.70). A standard score of 70% was established as the benchmark knowledge score.

Assessment of Expeditionary Surgical Skills

Rigorous, detailed performance assessment instruments were used by expert assessors to capture skills assessment data. Assessments took place while the sample performed 30 trauma related procedures on fresh, selectively perfused cadaveric models as part of the Advanced Surgical Skills Exposures for Trauma Plus (ASSET+) course. The ASSET+ course is an adaptation of the American College of Surgeons ASSET™ course, and for each procedure includes one-to-one assessment of participants by experienced trauma surgeons.

To assure fairness associated with anatomical variances between cadavers, assessment instruments included evidence-based score weighting for case difficulty. Scale scores for assessments were based on statistical modeling for each procedural step and included the accuracy, efficiency, and independence in performing each step of the surgical procedures. Psychometric support for skills performance instruments includes content, convergent, criterion, and predictive validity evidence ($p<.05$) and test-retest reliability >.90. A benchmark score of 90% was established for surgical skills associated with each procedure, which reflects the minimum score for accurate and independent performance of all procedural requirements.

Analyses

We calculated descriptive statistics for all knowledge and skills competency outcomes. We examined the impacts of deployment status and sub-specialty training on domain knowledge through analysis of variance. We calculated correlations to examine for statistically significant relationships between knowledge and skills competencies, as well as to examine the relationships between procedural skills competencies and the metric data associated with the volume and variance of routine surgical care during non-deployment. Statistical significance was set at $p < 0.05$. All statistical analyses were performed using IBM SPSS Statistics v. 27.

RESULTS

Knowledge Assessment Outcomes

The distribution of knowledge scores for the sample met the conditions of normality, with a mean composite score for all eight categories of 72% (standard deviation, 5%). The overall score met the specified benchmark criterion of 70%; however, the mean scores did not meet the benchmark performance criteria for either head and spine injury or universal domains categories. Additional knowledge deficits were identified in all sub-categories, and these deficits aligned with performance areas that are rarely performed during typical general surgery practice. The distribution of knowledge gaps by category are presented in Figure 1. Eighteen sub-categories in these content areas were missed by 85% of test takers.

Surgeons with sub-specialty training in critical care, trauma, and burn surgery had significantly higher knowledge scores than those from other sub-specialties ($p<0.001$). The distribution of knowledge scores by sub-specialty focus are presented in Figure 2. Surgeons with greater deployment experience in combat zones had significantly higher knowledge scores than those with either no experience or minimal experience in both combat and non-combat deployed environments ($p<0.05$). These data provide additional convergent validity evidence for exam integrity.

Skills Assessment Outcomes

The composite (30 procedures) skills scores for the sample ranged from 23 to 100. The mean composite score for all procedural skills was 75.88% (standard deviation, 13.73%), which was below the benchmark score of 90%. Less than 3% of the sample were able to correctly perform all procedural skills to the benchmark standard, and less than 1% were able to do so independently. The mean scores per procedure are shown in Figure 3. The lowest procedural scores were for procedures that are rarely, if ever, performed by non-trauma surgical specialties, including supraceliac control of the aorta, subclavian artery exposure, management of cardiac injury, left-to-right medial visceral rotation to expose critical vessels in the abdomen, popliteal artery exposure, pulmonary tractotomy, median sternotomy, and fasciotomies of the lower leg, upper extremity, and thigh. The only procedure that met the performance benchmark was Cricothyroidotomy.

Correlation Knowledge, Skills, and Applied Practice Metric

There were no significant correlations between knowledge scores and procedural skills scores, confirming that the assessment instrumentation differentiated between these two dimensions of overall performance. Likewise, there were no significant correlations between knowledge scores and the metric scores describing routine surgical care (KSA metric). This confirms the distinctions between the knowledge requirements for routine surgical practice and those required for expeditionary surgical practice.

There were significant correlations between the metric scores for routine surgical care (KSA metric) and the procedural skills scores for rarely performed life-threatening procedures, including the exposure of critical structures and the ability to control blood vessels ($p<.05$). Figure 4 illustrates the correlation between the applied practice metric scores (KSA metric) and the procedural skills scores for eight procedures that are critical competencies for expeditionary surgeons.

DISCUSSION

The outcomes from this study demonstrate the value of the KSA framework for capturing representative data for each performance dimension in the domain of expeditionary surgery, and the comparison of those performance data against pre-defined benchmarks to assure competency. The assessment data successfully identified specific competency gap areas in both knowledge and skills that aligned with performance categories that rarely required during non-deployment surgical practice.

The comprehensiveness of the knowledge exam allowed us to identify sub-category gaps in critical areas that did not meet the desired benchmarks. Although overall knowledge scores met the established benchmark of 70%, knowledge gap areas were evident for all participants in domain sub-categories that are rarely required for most general surgeons. These content areas included transfusion and resuscitation, wounds and amputations, head and spine

injuries, and expeditionary unique factors such as the management of unexploded ordinance, mass casualty situations, care of military working dogs, and working with local populations. For example, general surgeons rarely manage head and spine injuries, nor are they required to manage and transport patients between multiple facilities (universal domains). These outcomes were reinforced by the ability to demonstrate a higher readiness among those surgeons with sub-specialty training and deployment experience in areas that demonstrated expeditionary capabilities, such as trauma and critical care within deployed contexts.

Similarly, the precision of the skills assessment instrumentation facilitated the capture of detailed performance outcomes associated with the accurate and independent management of traumatic injuries, and revealed significant performance gaps for 29 of 30 procedures. The assessed procedures are rarely, if ever, performed by general surgeons as part of their routine surgical practice; however, they are required for expeditionary surgeons. Importantly, the surgical skills performance scores for these critical procedures correlated significantly with the applied practice metric scores, which demonstrates the value of a consistent and diverse surgical practice on the ability to perform essential procedures in the expeditionary context. The correlation of a robust surgical practice with the surgical skills required to provide optimal combat casualty care for our service members is of paramount significance. The correlation of these data demonstrate that foundational procedural skills are common across all surgical specialities within both routine and expeditionary practice, and underscore the importance of an active, diverse routine surgical practice for maintaining essential surgical skills that readily transfer to applied trauma care.

Critically, the data associated with the three dimensions (knowledge, skills, and abilities) demonstrate domain convergence, confirming the suitability of the KSA framework for developing competency-based performance criteria. The confirmation of this framework establishes an evidence-base and strong justification for implementing multi-requirement specifications for knowledge, skills and abilities to mitigate decay within the clinical readiness lifecycle. To assure ongoing clinical readiness, knowledge assessment will be required every three years and skills assessment will be required every two years, in addition to the requirements for an active and diverse surgical practice. The data also underscore the need to develop resources that are widely available for all expeditionary surgeons to reference on-demand, and minimally pre-deployment, to close any capability gaps and assure their readiness in the expeditionary environment.

The identification of capability gaps is central to assuring clinical readiness. It provides relevant information to individuals, commanders, and the military health system about what is required to assure clinicians are prepared to meet their mission requirements - to provide the best possible care in support of military operations. These data provide evidence-based requirements for the development of targeted training and other resources designed to support the capabilities of individual clinicians. The outcomes of this study demonstrate that assuring readiness gaps are both identified and addressed requires routine multi-dimensional assessment in the performance domain and underscores the critical need to develop focused training resources to assure individual clinical competency and currency. Through the

development and implementation of standardized assessment, access to readily available training resources, and assuring opportunities to provide mission critical surgical care to patients as a routine part of professional practice, the KSA framework addresses both provider and mission clinical needs. We are in the process of applying these methods to other members of the combat casualty care team, including other surgical specialties, critical care medicine, emergency medicine, anesthesiology, and nursing. We are also developing team-based requirements for multi-disciplinary implementation.

We are developing on-line training modules in partnership with the American College of Surgeons to provide specialty specific, multimedia-based instruction to facilitate on-demand training designed to reduce knowledge gaps.[14-15] We have also developed an immersive procedural course for expeditionary surgeons to periodically rehearse and refresh their surgical skills (Bowyer, Andreatta, Armstrong, et al.).[16] Preliminary outcomes from this course demonstrate significant competency gains, with skills performance accuracy increasing from 1% to 99%, with 78% of participants demonstrating procedural independence after training.

In addition to the development of training and other resources that encourage expeditionary general surgeons to actively pursue information and practice opportunities, the outcomes from this study demonstrate that it is critical to participate in routine and diverse surgical practice to maintain surgical capabilities. A dashboard that tracks KSA metrics for every military surgeon is accessible by surgeons, commanders, and the Military Health System to facilitate the management of care services with an eye towards maintaining readiness.[1]

A limitation of this study is that we did not directly measure performance of professional abilities in applied surgical practice. This performance dimension is inherently measurable; however, it is practically difficult to measure without significant investment and participation by personnel within the relevant environments. However, the addition of more direct measurement in applied practice could further enhance these outcomes over time, especially measures captured during deployment.

The Clinical Readiness Program is based on a KSA framework for the domain of expeditionary surgery, but has implications far beyond the battlefield.[4] These outcomes provide a strong evidence base for actionable recommendations for maintenance of competency requirements that are broadly transferrable to both expeditionary and civilian general surgeons.[13] Beyond the value for evaluating the capabilities of expeditionary general surgeons, the outcomes of this study have broader implications for the maintenance of certification and readiness of civilian general surgeons to deal with ever-increasing mass casualty events in the United States, as well as challenges associated with rural and humanitarian surgery, board certification, and expansion of practice credentialing for surgeons and physicians in other specialties. [13-14, 17]

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Figure 1. Knowledge gap areas as a percent total exam score.

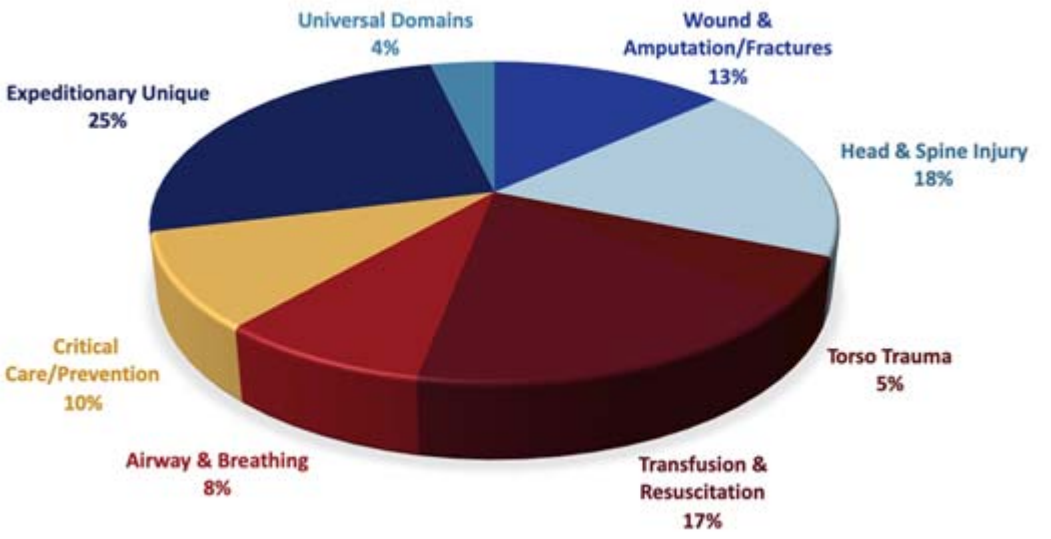

Figure 2: Knowledge score (percent correct) distributions by sub-specialty training.

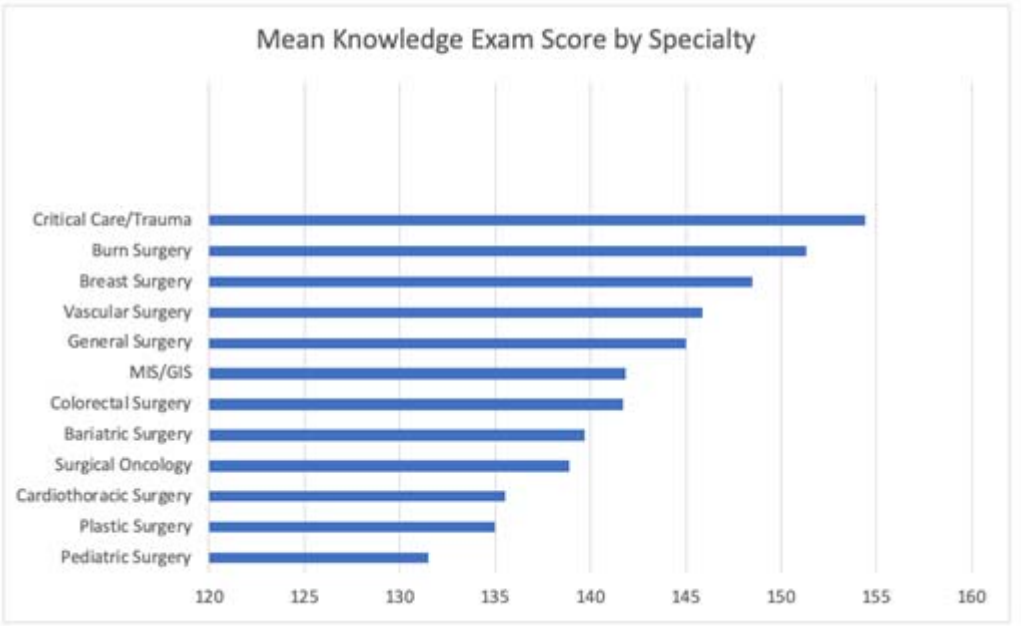

Figure 3: Mean procedural skills score distributions by procedure.

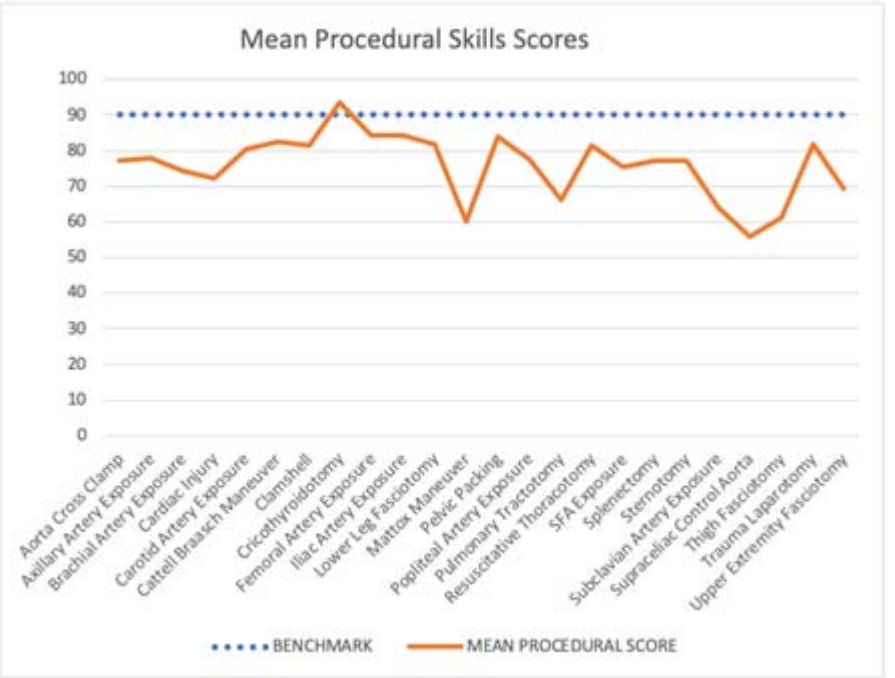

Figure 4: Correlation between critical procedural skills and applied practice metric scores.

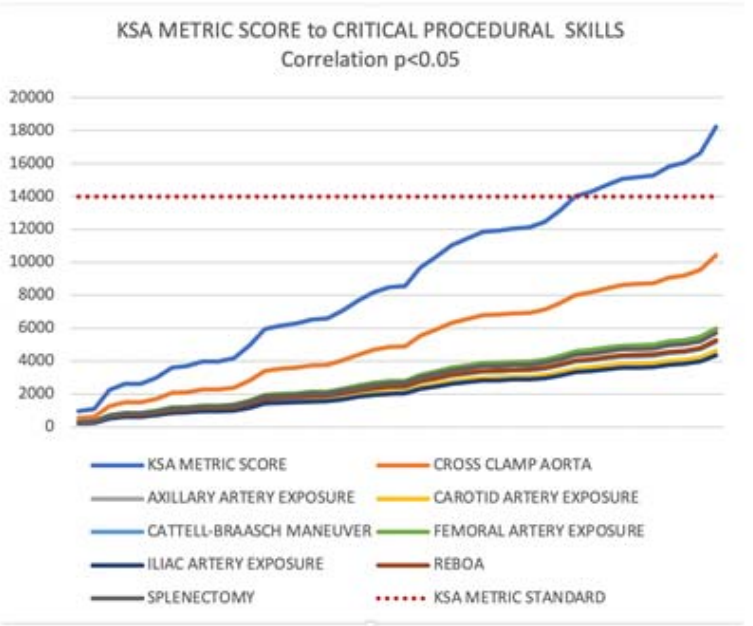

Table 1: Domain Categories and Sub-Categories for Expeditionary General Surgeons

Domain Categories	**Domain Sub-Categories**
Wound, Amputation, Fractures	Management of War Wounds
	Compartment Syndrome and Fasciotomy
	Amputation
	Burn Care
	Dismounted Complex Blast Injury
	Extremity Trauma/Hands and Feet
Head and Spine Injury	Cervical and Thoracic and Lumbar Spine Injury
	Concussion/Mild Traumatic Brain Injury
	Neurosurgical Management
	Cervical Spine Evaluation
	Management of Severe Head Injury
Torso Trauma	Pelvic Fracture Care
	Blunt Abdominal Trauma
	Damage Control Surgery
	Thoracic Trauma
	Wartime Vascular Injury
Transfusion and Resuscitation	Frozen Blood
	Damage Control Resuscitation
	Fresh Whole Blood
	Injury Documentation
	Resuscitative Endovascular Balloon Occlusion of Aorta
	Emergency Thoracotomy
Airway and Breathing	Trauma Airway Management
	Acute Respiratory Failure
	Trauma Anesthesia
	Inhalation Injury
Critical Care/Prevention	Hypothermia Prevention
	Prevention of Venous Thromboembolism
	Catastrophic Care
	Infection Control
	Management of Pain, Anxiety, Delirium
	Critical Care Additional
Expeditionary Unique	Unexploded Ordinance Management
	Tactical Combat Casualty Care/Pre-Hospital Care
	Enemy Prisoner of War & Detainee Care
	Pediatric Trauma
	Intra-Theater Transport
	Clinical Management of Military Working Dogs
	Initial Care of Ocular/Adnexal Injuries
	Joint Trauma System

	Urologic Trauma
	OBGYN Emergencies
Universal Domains	Practiced Based Learning and Improvement
	Interpersonal and Communication Skills
	Professionalism
	Systems Based Practice

Table 2: Sample Distribution by Surgical Specialty

Specialty Distribution
General Surgery: 62%
Critical Care/Trauma: 11%
MIS/GIS: 5%
Colorectal Surgery: 4%
Vascular Surgery: 4%
Surgical Oncology: 4%
Burn Surgery: 3%
Plastic Surgery: 2%
Pediatric Surgery: 2%
Breast Surgery: 1%
Bariatric Surgery: 1%
Cardiothoracic Surgery: 1%

Table 3: Sample Distribution by Professional Experience

Professional Experience
< 5-years (66%)
5-10-years (18%)
11- 20-years (11%)
> 20-years (5%)

Table 4: Sample Distribution by Deployment History

Number of Deployments	**Time in Combat Zones**	**Time in Non-Combat Zones**
Minimum: None	Minimum: None	Minimum: None
Maximum:15 Deployments	Maximum: > 5 years	Maximum: > 5 years
Mean: 3.45 Deployments	Mode: 4-6 months	Mode: 1-3 months
Standard Deviation: 3.87 Deployments		