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TITLE: Emergency Refreshing of Combat Surgical Skills

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CONTRACTING ORGANIZATION: University of Maryland, Baltimore, MD

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13. SUPPLEMENTARY NOTES

14. ABSTRACT

This project explores techniques for rapid (emergency) refreshing of critical combat surgical skills to improve the performance and outcome of trauma surgical procedures. The project capitalizes upon metrics developed in a previously funded project (W81XWH-13-2-0028) that include: knowledge, anatomy, management, procedural steps, technical skills, errors, time to complete the procedures, overall success and global rating scales. We will study performance of surgeons with varying trauma experience who trained previously in Advanced Surgical Skills for Exposure in Trauma procedures. The interventions include a video review immediately pre-operatively or on demand intra-operatively and intra-operative telementor guidance from a remotely located expert. During this first year of the project both interventions were developed and tested. Preliminary data assessing fasciotomy success suggest improvement in the number of compartments decompressed using the video review tool. The goals of the coming year are to continue subject evaluations and begin data analysis, including analysis of surgeons' 'think-alouds' and telementor interaction.

15. SUBJECT TERMS

Vascular injury, Combat wounds, Surgical training, Education, Surgical intervention, Telementoring, Video review, Skill retention, Error prevention, Error correction

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1. INTRODUCTION:

This research project aimed to maximize healthcare professionals' performance, including cognitive and psychomotor skills, during life or limb-saving trauma procedures by use of near time emergency refreshing interventions. The interventions tested consisted of (1) pre- and intraoperative video review and (2) intra-operative telementoring assistance. The primary outcome measures were surgeon performance of 4 critical trauma procedures on cadavers. In addition to testing these specific performance enhancing tools, behavioral models of surgeon performance were studied to evaluate surgeons' cognitive processes during these procedures. This information can be used to guide the design of future interventions.

2. KEYWORDS:

Vascular injury, Combat wounds, Surgical training, Education, Surgical intervention, Telementoring, Video review, Skill retention, Error prevention, Error correction

3. ACCOMPLISHMENTS:

What were the major goals of the project?

1. Assessment of whether static video refreshing of knowledge or dynamic interaction with a telementor are effective at improving outcome of trauma surgical performance of vascular exposure and fasciotomy versus a no refresher control condition in unpreserved cadavers.
2. Development of video / image tools (video mental review, VMR) for mental review of key steps in the vascular exposure and fasciotomy procedures.
3. Development of telementoring (dynamic interactive telementoring, DIT) for remote mentoring in trauma procedures.
4. Evaluate 'think-aloud' from the surgeon audio recordings for content and affective metrics, as well as surgeons' self-reported perceptions of self-confidence/helpfulness from VMR and DIT.

What was accomplished under these goals?

1. Recruitment and testing for experimental and control participants has concluded. A grand total of 56% (59 out of 105) of planned evaluations were completed. These are surgeons who have taken the Advanced Surgical Skills for Exposure in Trauma (ASSET) course within 2-6 years and completed training or are in their final year of training, equivalent to being at or near deployment ready. Enrollment was lower than anticipated due to having run out of the pool of subjects, as we had contacted all ASSET trained surgeons in the US for recruitment, thus utilizing the complete pool of possible subjects. This was compounded by the inability to complete our final enrolled subjects due to widespread COVID-19 prohibitions on travel and on close-quarters human subjects research. Although recruitment is less than proposed due to these factors, there was ample statistical power in the data allowing conclusions of the effacy of both interventions to be achieved with high confidence.
2. We found marked improvement in successful fasciotomy (Upper Extremity Fasciotomy [UEF] and Lower Extremity Fasciotomy [LEF]) completion with both video review (Smart Technical Assistance Tool [STAT]) and telementor (Telementor Initiated Procedure Support [TIPS]) interventions indicating just in time support improves outcome.
3. There were no improvements in patient management or pathophysiologic understanding with either intervention. This was expected, as neither intervention focused on patient management or pathophysiologic understanding of the clinical procedure allowing these components of the performance evaluation to serve as internal controls for the intervention efficacy. (Figure 1)
4. Both interventions show improvements in anatomic knowledge and a marked improvement in the individual procedure components, both of which are targeted by the interventions. In particular procedural skill was a key intervention target. (Figure 1; P<0.001)

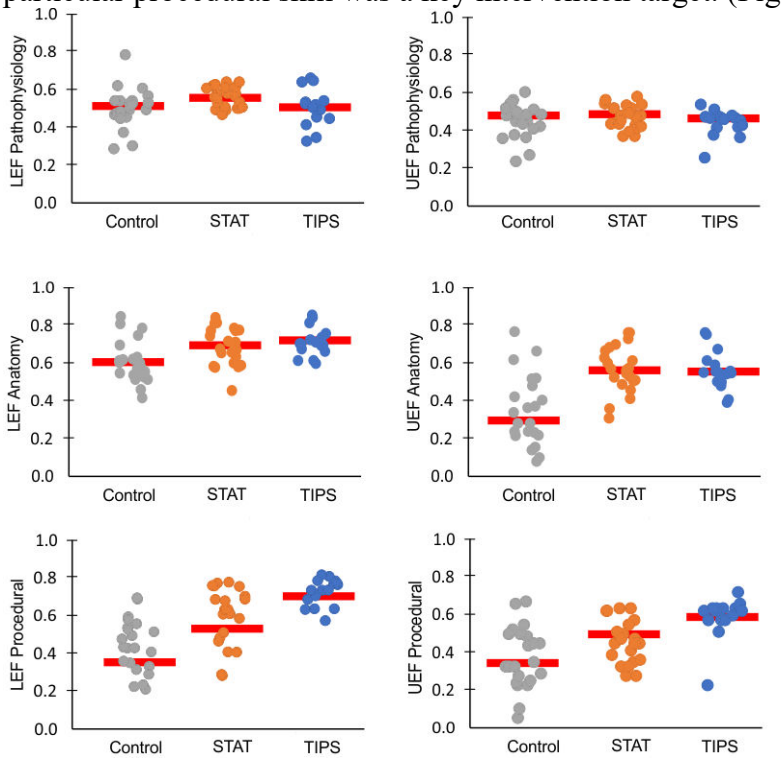

Figure 1: Participant Pathophysiology, Anatomy and Individual Procedure Score (IPS) in LEF and UEF with control (grey), STAT (orange), and TIPS (blue) study groups.

5. STAT and TIPS interventions were highly effective in improving the number of compartments successfully decompressed by surgeons in the study, as we had hypothesized. (Figure 2)

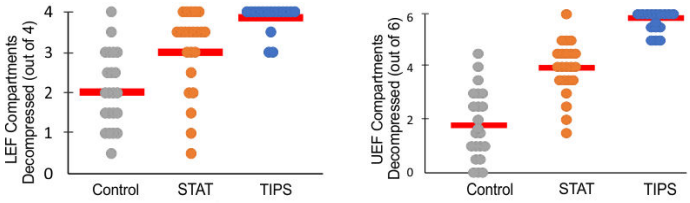

Figure 2: Participant success (# of compartments decompressed in LEF and UEF in control (grey), STAT (orange), and TIPS (blue) study groups.

5. Cross correlations show that procedural knowledge correlates very strongly with success rate in outcome of fasciotomy. The control study group has lower procedural score component and lower likelihood of successful compartment decompression, while STAT and TIPS study groups exhibit improved procedural scores that correlated with improved compartment decompression. (Figure 3)

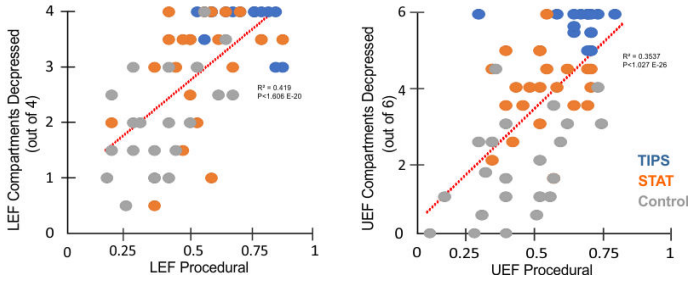

Figure 3: Participant success (# of compartments decompressed in LEF and UEF) vs. Procedural IPS component score in Control (grey), STAT (orange) and TIPS (blue) study groups.

6. Preliminary assessment of vascular access procedures indicates improvement in performance, though of lower magnitude seen with the fasciotomies. This may reflect either that these procedures tend to be easier (fewer and less technical steps) or that surgeons are generally more familiar with these procedures. They may have started with a higher baseline of skill and knowledge with vascular control procedures than fasciotomies. This observation, if consistent, would emphasize the value to an intervention for the uncommon procedures and be consistent with work in the literature showing that familiarity is a high predictor of success in procedures.
7. Cognitive analysis showed that the TIPS intervention was associated with a very strong increase in cognitive use of Expressives (how the surgeon feels about their work) and in Positivity (positive emotional state). This supports our hypothesis that having a telementor provides cognitive and responsibility 'off-loading' or 'sharing' during the performance of the procedure reducing worry/stress in the surgeon and producing a more positive mental state. (Figure 4)

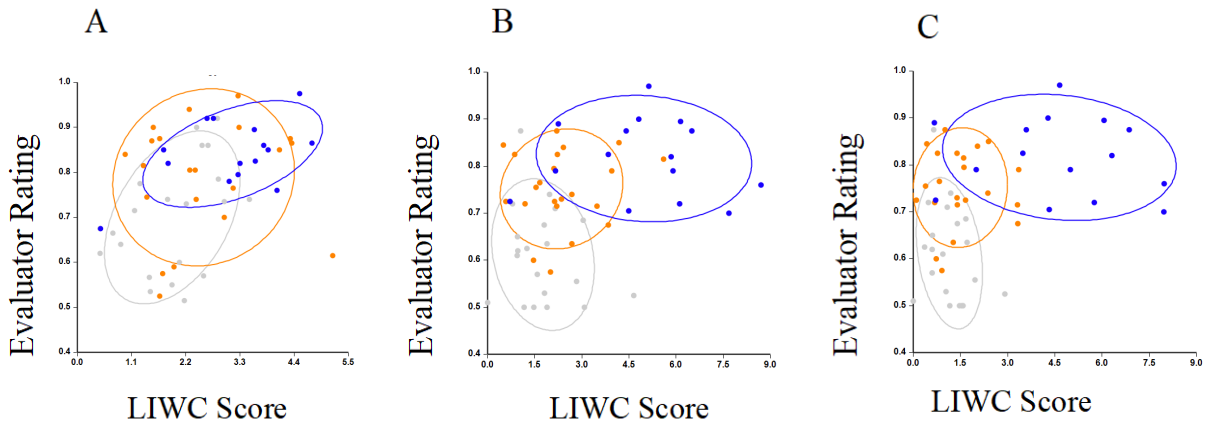

Figure 4: Changes in linguistic analysis (LIWC) vs. evaluator rating in Assent Score (indicative of agreement, A), Expressive Score, (how the surgeon feels about the situation, B), and Positivity Score (positive emotional state / status, C) between control (grey), STAT (orange), and TIPS (blue) study groups. The circles show the nearest neighbor confidence statistics line.

9. Linguistic analysis from the surgeon 'think-aloud' protocols also correlated to performance, with the overall readiness to perform the procedures rating. This positive correlation was strongest with Assent cognition (expressive of agreement), indicative of intervention efficacy in coordinated work with telementoring support (Figure 4). This cognitive positivity effect was negligible with the STAT intervention, even though performance was improved with STAT. This suggests the cognitive/responsibility stress load is not reduced by a static tool and is only reduced when another surgeon is available for consultation. Thus, provision of informational tools may not be sufficient to alleviate the stress of uncommon procedures, even though it does significantly raise overall performance of the surgeon. (Figure 4)
10. Surgeon verbal content analysis from the think-aloud protocols further suggests that the TIPS protocols are encouraging cognitive engagement by the surgeon. Interestingly, the STAT intervention may have a slight decrease in cognitive engagement. Such a finding could indicate that when using a reference type of tool, a surgeon is relying more on the tool and less on their own 'working out a problem'. This has important implications since cognitive engagement is a key component of experiential increase in skill performance. The use of a support tool may provide less 'learning experience' than unassisted performance, although the risk of incorrect procedure performance is of sufficient importance that 'learning through mistake' when a wounded service member's health is on the line is clearly not a preferred training method.
11. There was an inverse correlation between the telementor word count and the surgeons' performance. This is not unexpected, as a well performing surgeon needs less telementor prompting support (less telementor speech), but also highlights the need to avoid unnecessary interruptions or distractions in telementoring when performance is adequate.
12. The overall quantity of feedback, whether positive or negative, by the telementor correlated with performance.

What opportunities for training and professional development has the project provided?

1. Experienced evaluators (surgeons and anatomists) trained new evaluators on the procedures and protocols of the project and reviewed each procedure to ensure proficiency of new evaluators.
2. The project supported a graduate student who contributed to the analysis of the cognitive factors with both interventions.
3. Surgeons participating in the project had the opportunity to practice the skills and receive feedback on their performance from an evaluator.

How were the results disseminated to communities of interest?

Nothing to report.

What do you plan to do during the next reporting period to accomplish the goals?

Nothing to report

4. IMPACT:

What was the impact on the development of the principal discipline(s) of the project?

The proof of principle that an emergency refresher of procedural and anatomic information can significantly improve outcome strongly indicates that such interventions are a viable way to enhance patient outcome in cases where a surgeon needs to perform a procedure with which they are not familiar. This finding formed the basis for a grant submission proposing to expand the tool to a full product (the complete ASSET course) covering the major trauma procedures required for a surgeon deployed to a region of military operations. These findings could also impact surgical care in non-military, under-resourced situations.

What was the impact on other disciplines?

The project aids the incorporation of key medical issues to human factors research on interactions between a telementor and subject. This is adjusting how our human factors experts are viewing the dynamics of such interaction in the context of surgery, as well as several general principles the data is supporting.

What was the impact on technology transfer?

The tools (video review tool, telementor scripts, and audio-visual technology) have been finalized for this project and could be used by the military and in other hospital settings to help improve the outcome for these four surgical procedures.

What was the impact on society beyond science and technology?

Nothing to report

5. CHANGES/PROBLEMS:

The intent had been to extend recruitment as part of a no-cost-extension of the project, as enrollment had been undershooting expectations. Unfortunately, that recruitment and participant evaluation extension phase was terminated due to the covid-19 pandemic resulting in IRB restrictions on human research studies as well as travel. We thus proceeded into the final data analysis phase. There was higher statistical power than expected in our initial calculation, as both interventions were more effective than projected with respect to the fasciotomy procedures. This allowed for definitive outcome determination of the intervention effectiveness even with lower enrollment.

Actual or anticipated problems or delays and actions or plans to resolve them

Nothing to report.

Changes that had a significant impact on expenditures

Nothing to report.

Significant changes in use or care of human subjects, vertebrate animals, biohazards, and/or select agents

Significant changes in use or care of human subjects

Nothing to report.

Significant changes in use or care of vertebrate animals

N/A

Significant changes in use of biohazards and/or select agents

Nothing to report.

6. PRODUCTS:

- **Publications, conference papers, and presentations**

Journal publications. .

Quantitative analysis of intermuscular septa in the leg: implications for trauma surgery. Agandi L, Fuller K, Sonderman K, Tisherman SA, Puche AC. *Trauma Surgery & Acute Care Open.* 2021;6:e000721.

Books or other non-periodical, one-time publications.

Nothing to report.

Other publications, conference papers and presentations.

Agandi LA, Pugh K, Tisherman SA, Puche A. 2021. Quantitative Analysis of Intermuscular Septa in the Leg: Implications for Trauma Surgery. *Trauma and Acute Care Open,* 2021;6:e000721.

Shah, C.S., Shalin, V.L., Pugh, K., Agandi, L., Puche, A., Tisherman, S. (2019). Communication patterns in remote interactive surgical training. In Proceedings of the Human Factors and Ergonomics Society Conference, Seattle, WA, October, 2019.

"Surface landmark identification & compartment decompression in performance of upper extremity fasciotomy" Pugh K, Agandi L, Tisherman S, and Puche A. Poster presentation at the American Association of Clinical Anatomists (AACA) annual meeting in Tulsa, OK, June, 2019.

"Can a telementor improve incision placement & vessel identification in exposure of femoral artery?" Agandi L. Pugh K, Tisherman S and Puche A. Oral platform presentation at the American Association of Clinical Anatomists (AACA) annual meeting in Tulsa, OK, June, 2019.

"Emergency, Just-In-Time Refreshing of Combat Trauma Surgical Skills, Via Video Review or Telementoring, Dramatically Improves Surgeon Performance of Extremity Fasciotomies" Tisherman SA, Puche A, Pugh K, Agandi K. Oral platform presentation at the Military Health System Research Symposium, Orlando, FL, August, 2019.

- **Website(s) or other Internet site(s)**

Nothing to report.

- **Technologies or techniques**

Nothing to report. (Project technology explained in impact section).

- **Inventions, patent applications, and/or licenses**

Nothing to report.

- **Other Products**

Nothing to report.

7. PARTICIPANTS & OTHER COLLABORATING ORGANIZATIONS

What individuals have worked on the project?

Name: Samuel A. Tisherman
Project Role: Co-PI
Researcher Identifier (e.g. ORCID ID): https://orcid.org/0000-0003-3810-3729
Nearest person month worked: 0.6
Contribution to Project: Dr. Tisherman has performed work in the development and implementation of surgical intervention development and evaluation on surgical performance.
Funding Support: W81XWH-17-2-0011

Name: Adam C. Puche
Project Role: Co-PI
Researcher Identifier (e.g. ORCID ID): 0000-0002-6847-1218
Nearest person month worked: 3
Contribution to Project: Dr Puche has performed work in the development and implementation of surgical intervention development and evaluation on surgical performance.
Funding Support: W81XWH-17-2-0011

Name: Kristy (Pugh) Fuller, MS
Project Role: Research Lead Specialist
Researcher Identifier (e.g. ORCID ID): n/a
Nearest person month worked: 12
Contribution to Project: Kristy has performed work in the development and implementation of surgical intervention development and evaluation on surgical performance.
Funding Support: W81XWH-17-2-0011

Name: Lorreen Agandi
Project Role: Research Assistant, Clinical
Researcher Identifier (e.g. ORCID ID): n/a
Nearest person month worked: 12
Contribution to Project: Lorreen has performed work in the development and implementation of surgical intervention development and evaluation on surgical performance.
Funding Support: W81XWH-17-2-0011

Name: Valerie Shalin
Project Role: Sub-award recipient
Researcher Identifier (e.g. ORCID ID): n/a
Nearest person month worked: 0.75
Contribution to Project: Dr. Shalin has contributed to the development of the scenario scripts for dynamic interactive telementoring.
Funding Support: W81XWH-17-2-0011

Name: Claire Shah
Project Role: Sub-award recipient
Researcher Identifier (e.g. ORCID ID): n/a
Nearest person month worked: 4
Contribution to Project: Claire has contributed to the development of the scenario scripts for dynamic interactive telementoring.
Funding Support: W81XWH-17-2-0011

Has there been a change in the active other support of the PD/PI(s) or senior/key personnel since the last reporting period?

Nothing to report.

What other organizations were involved as partners?

Organization Name: Wright State University
Location of Organization: Dayton, Ohio, USA
Partner's contribution to the project: contributed to the development of the scenario scripts for dynamic interactive telementoring.

Organization Name: Maryland State Anatomy Board
Location of Organization: Baltimore, Maryland, USA
Partner's contribution to the project: Provides cadavers and lab space for the project.

8. SPECIAL REPORTING REQUIREMENTS

COLLABORATIVE AWARDS:

QUAD CHARTS:

9. APPENDICES:

Appendix A: Additional reporting requirements
Appendix B: Meeting abstracts and manuscripts (separate file)

Appendix A: Final report extra requirements:

1. List of equipment purchased:
    a. iPads x7*
    b. Computers x2*
    c. Bovie machine*
    d. Biopac*

*These purchases are of negligible residual value due to the age of the computer equipment at this time.

2. Transition plan:

We have utilized the data collected in this project as the basis for a congressionally directed funding application. Below is the abstract for that application.

Technical Abstract: "Surgical Technical Assistance Tool for Emergency Refreshing of Combat Surgical Skills"

Multi-Principal Investigators (mPIs): Adam Puche, PhD, and Samuel A. Tisherman, MD, FACS, FCCM.

Background: A substantial fraction of medical care in combat environments revolves around field stabilization, followed by provision of trauma surgical support at a forward medical facility. As soon as medically possible, casualties are transferred to major medical facilities outside the immediate combat zone. Expeditious evacuation at each chain-of-care stage relies upon adequately protected aeromedical support in the engagement theatre. Delays in aeromedical evacuation may elevate patient load in regional forward surgical sites. In addition, during high intensity conflicts the number of casualties could rapidly exceed the number of available trauma surgeons regionally. In such situations, surgeons of any specialty will need to provide trauma surgical care, performing procedures with which they may have limited familiarity. Even trauma surgeons undertake some procedures infrequently and will be called upon to perform unfamiliar procedures in the absence of a specialist. In the paradigm change where advanced medical support is closer to the point of injury, how can we provide emergency refreshing of procedural skills to surgeons being called upon to perform such procedures?

Objective/Hypothesis: The objective of this proposal is to provide a knowledge- and skills-based tool that a surgeon could use to improve performance of procedures in which they have limited experience. In our previous award W81XWH-17-2-0011 we showed that a video based step-by-step tool (the Surgical Technical Assistant Tool [STAT]), analogous to pre-flight or pre-engagement checklists common in military use, doubled the success probability of surgeons performing fasciotomies. This proposal builds on these findings to expand the STAT intervention from the proof-of-principle to a tool covering the full set of skills in the advanced Knowledge, Skills, Abilities (KSA) for the Advanced Surgical Skills for Exposure in Trauma (ASSET) Course. We hypothesize that surgeons provided with support via the STAT interface will demonstrate improved performance of the 30 critical procedures most important for the primary stabilization and care of a wounded armed forces service member.

Specific Aims: Aim 1: Deconstruction of the 30 additional critical trauma skill procedures into the component steps that are necessary for successful outcome of the procedure and develop the STAT intervention to cover those skills with touch and voice activation control interfaces. Aim 2: Evaluate surgeons performing each procedure with control (no support) and STAT (emergency refresher support), assessing their individual performance scores, cognitive state with think-aloud protocols, and stress levels with biometric telemetry recording. Aim 3: Cyclical development in which information from participant performance is fed back to refine component steps or sequences in which surgeons are observed to express uncertainty or perform poorly at the execution. Aim 4: Generate STAT emergency refresher videos utilizing a perfused cadaver model to simulate bleeding for a tool version with higher correspondence to the injured patient condition.

Study Design: Surgeons will be divided into two groups and asked to perform 5 procedures each (n=10 per procedure, total subjects for 30 procedures n=120), one group will have the use of the STAT intervention and the other group will serve as a control with no intervention support. Performance will be assessed and compared using their individual procedure score, rate of critical errors and overall performance based upon metrics developed by consensus of our team of experts as per previous projects W81XWH-13-2-0028 and W81XWH-17-2-0011.

Impact: This work will evaluate a knowledge-based solution to provide support to surgeons who may need to perform unfamiliar procedures. The STAT intervention has both a low deployment cost and is highly mobile, consisting of procedural information digitally stored on an electronic device (e.g. tablet, phone, computer, or heads-up display). Even trained surgeons show substantial error rates on trauma procedures through lack of currency/experience. Even the previous intensive training surgeons receive cannot mitigate these errors in unfamiliar procedures. The STAT proposed here will give the key knowledge-based procedural support when performing these procedures to improve a wounded soldier's probability of optimal outcome and survival under these circumstances. This support is an essential tool that needs to be added to the military surgeon 'tool-kit'.

3. Bibliography of publications, abstracts and personnel receiving pay:
    a. Publications:
        i. Agandi LA, Pugh K, Tisherman SA, Puche A. 2021. Quantitative Analysis of Intermuscular Septa in the Leg: Implications for Trauma Surgery. *Trauma and Acute Care Open,* 2021;6:e000721.
        ii. Shah CS, Shalin V, Pugh K, Agandi L, Puche A, Tisherman SA. Communication Patterns in Remote, Interactive Surgical Training. *Proceedings of the Human Factors and Ergonomics Society, 2019 Annual Meeting.*
    b. Abstracts:
        i. Pugh K, Agandi L, Tisherman SA, Puche A. Surface Landmark Identification & Compartment Decompression in Performance of Upper Extremity Fasciotomy. *Submitted, Accepted, and presented as poster presentation 2019 to American Association of Clinical Anatomists.*
        ii. Agandi L, Pugh K, Tisherman SA, Puche A. Can a Telementor Improve Incision Placement and Vessel Identification in Exposure of Femoral Artery? *Submitted, Accepted, and Presented as platform presentation 2019 to American Association of Clinical Anatomists.*

iii. Tisherman SA, Puche A, Pugh K, Agandi L. Emergency, just-in-time refreshing of combat trauma surgical skills, via telementoring or video review, dramatically improves surgeon performance of extremity fasciotomies. *Submitted, Accepted, and Presented 2019 at MHSRS.*

c. Personnel receiving pay:
   i. Dr. Adam Puche
   ii. Dr. Samuel Tisherman
   iii. Kristina Fuller
   iv. Lorreen Agandi