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A Randomized, Controlled, Blinded Evaluation of Augmenting Point-of-Care Ultrasound and Remote Telementored Ultrasound in Inexperienced Operators

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ABSTRACT

Background: Handheld ultrasound devices present an opportunity for prehospital sonographic assessment of trauma, even in the hands of novice operators commonly found in military, maritime, or other austere environments. However, the reliability of such point-of-care ultrasound (POCUS) examinations by novices is rightly questioned. A common strategy being examined to mitigate this reliability gap is remote mentoring by an expert.

Objectives: To assess the feasibility of utilizing POCUS in the hands of novice military or civilian emergency medicine service (EMS) providers, with and without the use of telementoring. To assess the mitigating or exacerbating effect telementoring may have on operator stress.

Methods: Thirty-seven inexperienced physicians and EMTs serving as first responders in military or civilian EMS were randomized to receive or not receive telementoring during three POCUS trials: live model, Simbionix trainer, and jugular phantom. Salivary cortisol was obtained before and after the trial. Heart rate variability monitoring was performed throughout the trial.

Results: There were no significant differences in clinical performance between the two groups. Iatrogenic complications of jugular venous catheterization were reduced by 26% in the telementored group ($P < 0.001$). Salivary cortisol levels dropped by 39% ($P < 0.001$) in the telementored group. Heart rate variability data also suggested mitigation of stress.

Conclusions: Telementoring of POCUS tasks was not found to improve performance by novices, but findings suggest that it may mitigate caregiver stress.

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KEY WORDS: point-of-care ultrasound (POCUS), telemedicine, trauma, telementoring, ultrasound

*Rubrum Coelis is a joint Israel–Canadian group founded by Itamar Netzer, Elon Glassberg, and Andrew W. Kirkpatrick. Members who participated in this study are listed in alphabetical order.

Prehospital trauma care was already undergoing disruptive changes before coronavirus disease 2019 (COVID-19) struck and shifted the focus of the medical world. Among these changes is the growing availability and utilization of point-of-care ultrasound (POCUS) [1], especially as exemplified in handheld devices. These devices had already presented an opportunity for adoption of miniaturized ultrasound technology in the far forward and prehospital setting [2], whether in civilian ambulances, military trauma units, or humanitarian assistance and disaster relief (HADR) efforts. Prehospital POCUS was already deemed feasible in such extreme environments as helicopters, warzones, or austere/remote environments [3]. The global COVID-19 pandemic has provided a further use case for POCUS in the diagnosis and treatment of those affected [4,5]

Rapid adoption of the technology entails training and experience not easily administered to, or obtained by, caregivers who are novice POCUS users. Concern has been voiced about misdiagnoses in such scenarios [6], leading some policy makers to eschew the adoption of POCUS in the prehospital or outbreak setting. One possible solution to the training and experience gap maybe to provide experienced guidance when needed to those with only modest previous training using telemedicine. Telemedicine has been shown in the past to bridge this gap in various procedures, including POCUS [7-9]. However, reliance on wireless communications for the purpose of remote telementored ultrasound may be problematic in austere environments and in the military, where operational considerations may prohibit the use of wide-band communications.

An additional consideration to the question of performing prehospital POCUS in trauma is the level of knowledge or experience of the operator. Customarily, doctors are the ones performing ultrasound, especially in the hospital setting. However, in the case of novice operators, physicians might not outperform emergency medicine technicians (EMTs), having no significant advantage in skill or experience. To date, evidence to this effect has been scarce and equivocal [10], and the degree of assimilation of POCUS in emergency medical services relying on EMTs has been as low as 4.1% [11].

A further concern regarding telementoring is that of human factors. Many assumptions have been made in the past that prehospital providers appreciate input from remote experts, or even that remote experts possess helpful communication skills, neither of which should be assumed [12]. Furthermore, little has been written on the question of whether the act of telementoring might reduce the mentee's stress, or in fact, increase it. Caring for emergency casualties may increase responder stress [13], thereby hindering decision-making, but this can be mitigated using various strategies such as checklists or simulations [14]. Telementoring may be one such mitigating strategy; however, it may increase stress by creating additional distractions or excessive sensory stimulation [12].

In this study, we sought to randomly assess the feasibility of utilizing POCUS in the hands of novice military or civilian emergency medicine service (EMS) providers, with and without the use of telementoring, in military and civilian ambulances, and in naval ships and submarines, by EMTs in the former, and by EMTs or novice general practitioners in the latter. In addition, we assessed the possible mitigating effect of telementoring on operator stress. Stress was indirectly measured using physiological means, salivary cortisol [15], and heart rate variability [16]. This study is a continuation of the previous endeavors of the Rubrum Coelis Group [7,17] to advance the understanding and utilization of telemedicine in the prehospital treatment of trauma.

PATIENTS AND METHODS

Ethics approval for the trial was obtained by the Israeli Defense Force (IDF) institutional review board (approval no. 1992–2019). The trial was registered in the trial registry of the Israeli Ministry of Health. Prior to initiating the trial, all participants signed informed consent and completed a personal information questionnaire.

Forty EMTs and physicians were initially recruited from Magen David Adom (Israeli EMS provider), Medical Officer School in the IDF Military Medicine Academy (BAHAD 10), and the Israeli Navy and Israeli Air Force. All participants attended a 6-hour POCUS workshop one week prior to the trial. The workshop covered the topics of extended focused assessment with sonography for trauma (eFAST) [18] and ultrasound-guided jugular venous catheterization. The workshop included both lectures and hands-on experience on medical simulators, including Ultrasound Mentor by Simbionix (3D Systems, Colorado, USA) for eFAST and a Blue Phantom Internal Jugular Central Line Ultrasound Manikin (CAE, Florida, USA). Three potential participants dropped out before the trial, leaving 16 general practitioners (GPs) and 20 EMTs. The participants were divided into a mentored group (n=18) and an unmentored group (n=20) using block randomization [19]. The participants were not told if they would be mentored or unmentored until entering the area of the trial.

The POCUS tasks performed by all participants included:

- eFAST performed on a U/S Mentor by Simbionix. The Simbionix scenarios and their severity (as expressed in the amount of fluid visible in the scan) were pre-randomized for each participant using block randomization
- eFAST performed on a healthy participant
- Ultrasound-guided jugular venous catheterization performed on the Blue Phantom Manikin

Pretest salivary cortisol swabs were obtained by a licensed dentist, and the subjects were connected to a Polar rs800cx watch with a Polar h10 chest band for recording of heart rate variability (HRV). Prior to obtaining salivary cortisol swabs all respondents were questioned about nicotine and caffeine consumption, exercise and sleep prior to the trial, and evacuation of urine or feces. All were instructed not to ingest any caffeine prior to the trial. Resting state HRV was recorded for 5 minutes prior to the trial. Continuous HRV was recorded throughout the trial. Time to transition

between tasks was dropped from analysis. After completion of the trial all subjects gave another a cortisol salivary swab. A resting state HRV was recorded for 5 additional minutes. HRV data were analyzed for pNN50 (percentage of successive relative risk intervals that differ by more than 50 ms) and RMSDD (root mean square of successive relative risk interval differences) [16] using Kubios HRV Premium (version 3.3.0, Kuopio, Finland). For the sake of brevity, we did not list the technical setup for the trial.

SCORING

The Simbionix task was scored by an intensive care specialist and a trauma surgeon for accurately identifying the clinical feature of each of the eight sections of the eFAST exam (Morisson, Spleen/Kidney, Pericard, Pelvis, Right and Left Pleurae, Right and Left Pnuemothorax), whether pathological or normal, relative to the device's preset condition for each section in each scenario. Live model eFAST exam was scored for correct imaging and capture of each of the eight sections of the exam. This was appraised on site by an experienced mentor, and subsequently by the two physicians mentioned above, viewing only the captured images in each exam and being blinded to the subject's identity and mentorship status.

The jugular task was evaluated on site by two physicians for the following features:

- Vein was imaged in the center of the screen
- Subject drew simulated venous blood
- Guidewire was observed in the simulated vein using a longitudinal section
- Task was successful
- Adverse events were encountered
- Technically correct transverse section was performed
- Guidewire was placed in the center of the vein

The tests were subsequently reassessed by the corresponding author using only captured images. The second assessor was blinded to the participant's identity and mentorship status with regard to capturing a correct transverse section of the simulated vein and for longitudinal capturing of the guide inside the vein.

HEART RATE VARIABILITY

Vagal tone as measured by heart rate variability, was represented by the RMSDD and pNN50 metrics. Area under the curve (AOC) for these metrics was calculated during exercise stations, barring baseline, cool down and transition periods.

STATISTICAL ANALYSIS:

Statistical analyses were performed using SAS 9.4 software (SAS Institute Inc., Cary, NC, USA).

RESULTS

There were no significant differences between the groups participating in the trial in terms of basic demographics or background skill level or exposure [Table 1]. Most importantly, no significant differences were found between the mentored and unmentored arm in terms of task performance [Table 2]. An analysis of individual scores revealed similar results, with subjects in both groups scoring similarly in overall scores (79% success rate) with no statistically significant differences. However, an analysis of adverse events in the jugular task revealed that the unmentored group caused more events that could potentially lead to iatrogenic complications, with 44% adverse events in the unmentored group compared to 26% in the mentored group ($P < 0.001$).

Salivary cortisol was unexpectantly higher in the telementored vs. unmentored groups but not significantly so ($P = 0.055$). The salivary cortisol levels were dramatically reduced however, with the aid of remote telementoring (a 39.6% decline, $P < 0.001$), while without telementoring there was no statistically significant change in cortisol levels (20.43% increase, $P = 0.22$). In terms of HRV, mentorship reduced the AOC for RMSDD by 19.20% compared to the unmentored group ($P = 0.03$), and reduced AOC for pNN50 by 34.0% compared to the unmentored group ($P = 0.04$) [Figure 1, Figure 2]. This reduction is consistent with increased vagal tone, suggesting reduced mental stress.

DISCUSSION

Based on the results of this trial, we failed to find clinical improvement in performance between mentored and unmentored ultrasound operators with intensive and focused training experience. We assume that this result was because only a short time elapsed between the minimal ultrasound training provided to the subjects and the trial itself, and this pays tribute to the elegance of basic ultrasound training with motivated and engaged first responders [20]. While most differences in performance were not statistically significant, they did show a trend favoring telementoring over performing unguided POCUS. The 79% success rate we observed, however, corresponds with the results of other trials teaching POCUS skills to inexperienced caregivers [21], where average scores were around 77%. We recognized that intelligent first responders with basic training can utilize ultrasound to make critical diagnoses, but it is an unknown as to how long basic ultrasound skills are retrained by irregular users.

Doctors and specialists in training have shown to have remarkably rapid decays in ultrasound skills (already apparent at 1 and 3 months) without regular practice and reinforcement. This would suggest that skills and knowledge must be regularly refreshed and tested [22]. Thus, the Rubrum Coelis Group hoped to conduct a follow-up trial attempting to compare the two groups a year after the trial to assess the retention of such skills, but this endeavor was prevented due to the conditions of COVID-19. Nevertheless, the findings of the ultrasound exercises conducted suggest

Table 1. Demographics and background statistics of the study arms

	Study arm		Total
	Unmentored N=18	Mentored N=19	
Age in years ± standard deviation, (median, range)	33 ± 6.4 (30, 26–46)	29.5 ± 5.6 (27, 20–39)	31.2 ± 6.2 (29.5, 20–46)
Female sex	5 (31.25%)	1 (5.56%)	6 (17.65%)
Body mass index (kg/m^2) ± standard deviation, (median, range)	25.3 ± 3.2 (24.98, 20.7–33.0)	26.0 ± 4.5 (25.9, 19–35.2)	25.7 ± 3.9 (25.3, 19–35.2)
Confidence at performing ultrasound* (median, range)	2.3 ± 0.8 (2, 1–4)	2.7 ± 0.8 (2, 2–4)	2.5 ± 0.8 (2, 1–4)
Confident at performing jugular catheterization* (median, range)	2.6 ± 0.8 (3, 1–4)	3.3 ± 0.9 (3.5, 2–5)	3 ± 0.9 (3, 1–5)
Native language			
1	10 (62.5%)	15 (83.33%)	25 (73.53%)
2	3 (18.75%)	2 (11.11%)	5 (14.71%)
4	3 (18.75%)	1 (5.56%)	4 (11.76%)
English level of knowledge			
2	1 (6.25%)	0 (0%)	1 (2.94%)
3	1 (6.25%)	4 (22.22%)	5 (14.71%)
4	14 (87.5%)	13 (72.22%)	27 (79.41%)
5	0 (0%)	1 (5.56%)	1 (2.94%)
Profession: physician	8 (44.44%)	9 (47.37%)	17 (45.95%)
Central vein access experience**			
1	9 (56.25%)	14 (77.78%)	23 (67.65%)
2	4 (25%)	3 (16.67%)	7 (20.59%)
3	2 (12.5%)	1 (5.56%)	3 (8.82%)
4	1 (6.25%)	0 (0%)	1 (2.94%)
eFAST experience**			
1	10 (62.5%)	15 (83.33%)	25 (73.53%)
2	2 (12.5%)	3 (16.67%)	5 (14.71%)
3	4 (25%)	0 (0%)	4 (11.76%)

Categorical variables are presented with frequency and percent and continuous variables are presented with mean ± standard deviation (median, range)

*Confidence measured on 4-point Likert-type scale: 4 = very experienced, 1 = not experienced at all

**Experience measured on 4-point Likert-type scale: 4=very experienced, 1=not experienced at all

As we performed a randomized study, no *P*-values are presented for the baseline/background variables. However statistical tests performed to explore any significant difference between the study arms, after adjusting for multiple tests (Bonferroni correction), still revealed no significant differences between the study arms

eFAST = extended focused assessment with sonography for trauma

Table 2. Performance metrics for the central venous and eFAST tasks

	Study arm		Total	*P* value
	Not guided	guided		
	N=18	N=19		
Central venous cannulation task				
Jugular venous centered	18 (100%)	18 (94.74%)	36 (97.3%)	> 0.99
Jugular venous blood drawn	14 (77.78%)	18 (94.74%)	32 (86.49%)	0.1797
Wire in jugular venous using longitudinal section	12 (66.67%)	15 (78.95%)	27 (72.97%)	0.4756
Jugular venous overall success	13 (72.22%)	14 (73.68%)	27 (72.97%)	> 0.99
Jugular venous correct transverse section	10 (55.56%)	15 (78.95%)	25 (67.57%)	0.1287
Guidewire centered in jugular venous	10 (55.56%)	12 (63.16%)	22 (59.46%)	0.6378
eFAST task				
Morisson	16 (88.89%)	19 (100%)	35 (94.59%)	0.2297
Right pleura	11 (61.11%)	17 (89.47%)	28 (75.68%)	0.0625
Spleen kidney	14 (77.78%)	17 (89.47%)	31 (83.78%)	0.4048
Left pleura	13 (72.22%)	18 (94.74%)	31 (83.78%)	0.0897
Pericard	16 (88.89%)	17 (89.47%)	33 (89.19%)	> 0.99
Pelvis	16 (88.89%)	17 (89.47%)	33 (89.19%)	> 0.99
Right pneumothorax	13 (72.22%)	15 (78.95%)	28 (75.68%)	0.714
Left pneumothorax	14 (77.78%)	13 (68.42%)	27 (72.97%)	0.714
Final score (DQ)	4.78 ± 1.56 (6, 2–6)	5.21 ± 1.44 (6, 2–7)	5 ± 1.49 (6, 2–7)	0.4285
Final score (DT)	6.78 ± 1.35 (7, 4–8)	6.63 ± 1.67 (7, 1–8)	6.7 ± 1.51 (7, 1–8)	0.9239

Categorical variables are presented with frequency and percent and continuous variables are presented with mean ± standard deviation (median, range)

Interobserver reliability revealed an interclass correlation coefficient of 0.55, reflecting moderate reliability

Figure 1. pNN50 showing depressed heart rate variability in the mentored group

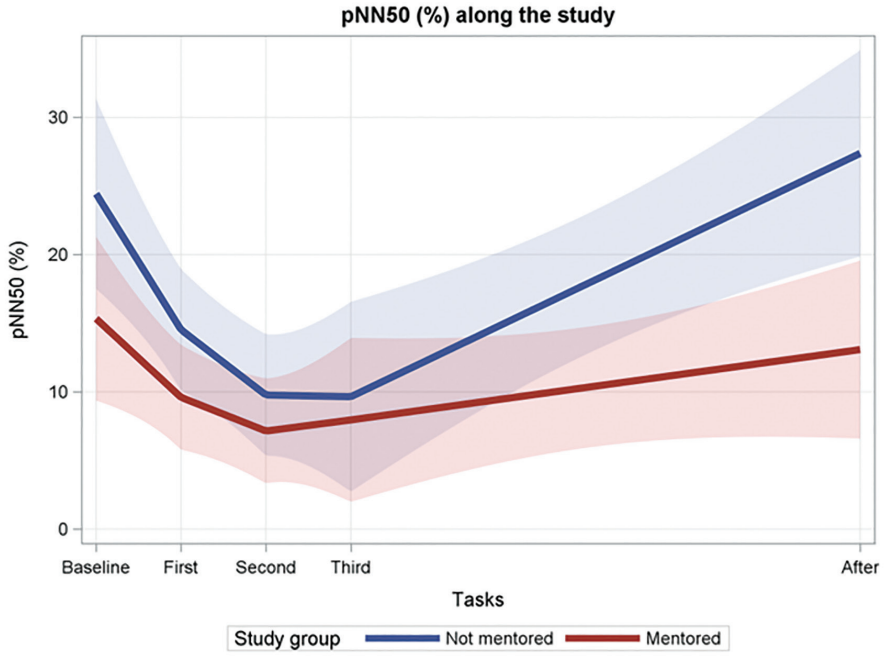
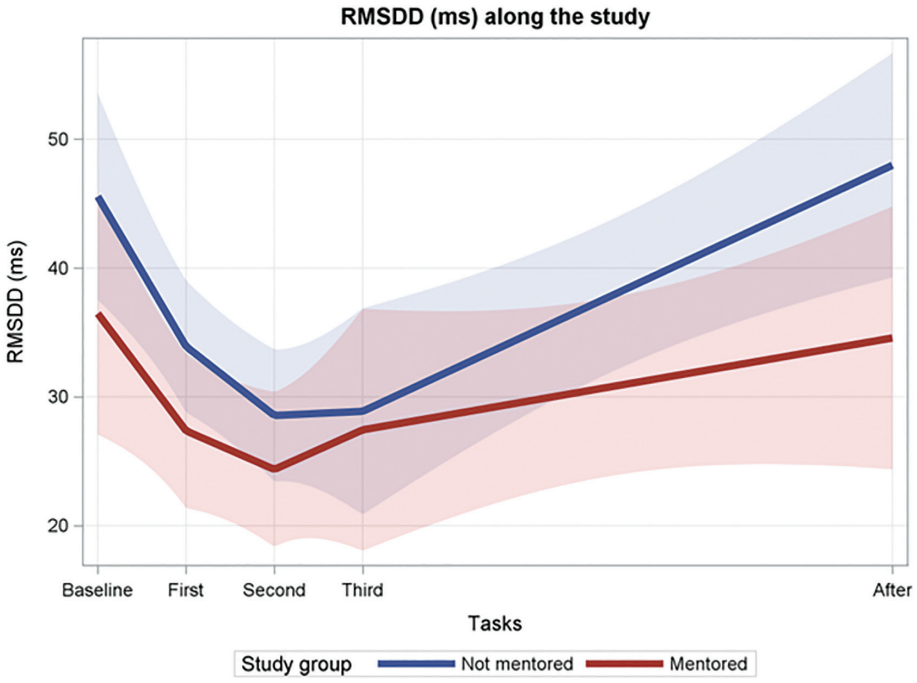


Figure 2. Root mean square of successive relative risk interval differences (RMSDD) between normal heartbeats showing depressed heart rate variability in the mentored group



that the use of POCUS by novices is feasible. We believe that it may be suitable for use in military or extreme environments, especially if mentorship is available. In addition, as the practice of telementoring sonographic exams improves, it may carry more weight when laymen, rather than novices, must be mentored in extremis. This situation would need to be further tested in the field using deployed caregivers and in an environment where casualty evacuation and care would not be solely dependent on the performance of POCUS. In addition, this idea has been recently demonstrated by others who provided remote telementored ultrasound to novice POCUS operators performing heart and lung evaluations [23], or eFAST venous thrombosis screening and central venous access [24].

As the area of telementoring of caregivers or laymen by more experienced caregivers continues to progress, we think that it may become important to develop and empirically test mentoring protocols that would ensure best practice [25]. Although it was beyond the scope of this study to test such protocols, we did use semi-structured protocols for the eFAST tasks and a structured protocol for the jugular task.

While there was no significant change in cortisol in the unmentored group during the trial, the mentored group displayed a statistically significant reduction in salivary cortisol. The HRV data were also found to display a change in vagal tone in the mentored group compared to the unmentored group. These findings further suggest that telementoring may have mitigated operator stress in the trial. This finding may be invaluable in extreme stress situations such as warzones, disasters, austere environments and outer space, leading to a higher quality of care, by mitigating caregiver stress.

LIMITATIONS

The trial was limited by a short elapsed time between POCUS instruction and performance. A further limitation includes the relatively small number of participants (n=37), representing a sample of convenience in what proved to be a logistically challenging trial.

CONCLUSIONS

Telementoring of POCUS tasks was not found to improve performance by novices. Our findings suggested that it may mitigate caregiver stress.

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