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Original Research

Investigation of Stethoscope Technology for En Route Care

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A B S T R A C T

Occupational challenges in air transport domains make auscultation with traditional stethoscopes difficult. This study aimed to investigate two commercial off-the-shelf stethoscopes for use in high noise military patient transport environments. The stethoscopes were assessed by Aeromedical Evacuation providers in a simulated C-130 trainer on live standardized mock patients. Device 1 was a dual-mode stethoscope developed for rotary wing military airframes. Device 2 was an electronic stethoscope developed for high noise civilian environments. Twenty clinicians performed cardiopulmonary auscultation using the devices on the same two standardized patients in a simulated C-130 then completed a subjective questionnaire on their ability to identify heart and lung sounds. Results indicated the dual-mode stethoscope had limited utility with clinician likeliness of use rated as low (median = 2; interquartile range = 1.75-3.25), whereas the electronic stethoscope had potential utility with likeliness of use rated as good (median = 4; interquartile range = 3.25-5). We conclude that further examination of devices capable of auscultation in high noise military environments is needed. In-flight testing of device 2 for use by end users has been completed and will be reported in a separate manuscript.

Stethoscopes are a key diagnostic tool for health care providers, enabling the noninvasive identification of patient diagnoses through auscultation. In conventional low decibel (dB) noise environments, providers are able to auscultate patients using traditional binaural stethoscopes. Traditionally, auscultated sounds range from 22 to 30 dB in free space and 65 to 70 dB through a conventional stethoscope.[1] However, high dB noise environments can prove a significant challenge to the auscultation process because the signals corresponding to bodily sounds are often within the spectrum of ambient noise.[2] Civilian health care providers in active environments such as intensive care units are often challenged by high dB noise.[3] There are several transmission pathways in which environmental noise can enter the stethoscope, including the acoustic tubing, earpieces, sensor housing, and even the patient's body through bony structures.[4] The presence of high dB noise within the ambient environment of aircraft, ambulances, or stationary facilities can limit a provider's ability to identify abnormal heart and lung sounds through auscultation, resulting in reliance on visual indications of changes in patient status or patient monitoring systems. Early detection of abnormal heart and lung sounds presents the opportunity of mitigating the detrimental impact of the physiologic compromise before physical signs are present, thus decreasing the potential for loss of life.

Noise and vibration are significantly increased in fast-paced military air transport domains such as en route care (ERC), combat casualty care including air medical evacuation (AE), critical care air transport (CCAT), and pararescue missions, making auscultation with a traditional stethoscope increasingly difficult for these military providers.[5,6] ERC transport encompasses patient care

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from the point of injury to more forward care systems throughout the United States and international continents. Several aspects of this ERC environment are dissimilar to traditional health care environments. During ERC, it may be necessary for personnel to listen to heart and lung sounds to identify abnormalities, such as listening to lung sounds to identify a collapsed lung and provide lifesaving medical intervention; however, in current operations, auscultation is hindered by noise and vibration, and the actual contributor of the most noise to the problem is still unknown. The accurate identification and medical intervention of certain issues, such as collapsed lungs, may significantly reduce the number of preventable deaths from the battlefield.[7]

The primary aircrafts used in an AE environment are the C-130 and the C-17. Ambient noise in the cabin of a C-130 is between 90 and 100 dB and around 86 dB on a C-17[8]; however, among all possible aircraft used for AE, the ambient noise can range from 80 to 110 dB.[1,9] However, noise is not the only stress that complicates the providers' ability to auscultate in the ERC environment. During ERC, patients are exposed to other stresses of flight such as fatigue, gravitational forces, decreased partial pressures of oxygen, vibration, thermal changes, decreased humidity, and barometric pressure changes.[10] These stresses can act in a cumulative manner, further complicating patient care in the ERC environment.[10,11] Structure-borne vibration is also an issue for auscultation. Structure-borne vibration caused by C-130 aircraft propulsion systems has been measured with the peak multiaxis vibration observed around 17 Hz (propeller rotation frequency) and 68 Hz or 102 Hz (blade passage frequency) depending on the C-130 variant.[12] Airborne vibration can also be transmitted to the body via acoustic waves and has been known to excite internal body resonances.[13] The nature of en route patient care may limit the resources available during flight, such as supplies, personnel, and medical equipment. These factors may contribute to the risk of negative patient outcomes, making it critical that AE and CCAT providers have essential assessment tools available for optimal patient care and safety. In an attempt to combat this problem, recent efforts have focused on the development of technology capable of enabling auscultation in high noise environments. Technology such as electronic or noise-immune stethoscopes (NISs) that can provide ERC caregivers with the same ability to perform cardiopulmonary auscultation as in a hospital setting may have the potential to greatly improve patient outcomes.

Although there have been several studies conducted on the applicability of innovative stethoscope technology for military environments focused primarily on rotary wing aircraft,[2,4] research on the use of NISs and electronic stethoscopes for Air Force AE providers is limited. Therefore, the aim of this study was to assess the feasibility of stethoscopes specifically developed for high noise environments, primarily the A SCOPE (device 1) produced by Active Signal Technologies (Linthicum Heights, MD) and the Thinklabs ONE (device 2) produced by Thinklabs Medical (Centennial, CO).

Device 1 is a dual-mode NIS developed for the US Army that uses both a passive electromechanical acoustic mode and a high-frequency 2.3-MHz Doppler ultrasound mode. Device 2 is a Food and Drug Administration approved, commercial off-the-shelf digital stethoscope with active filter technology. Device 1 was selected for the initial testing because of its approval for human use by the Food and Drug Administration and its history of comprehensive evaluations for military applications.[10] Device 2 was chosen after initial testing in a simulated high noise Air Force environment yielded positive results. In addition, device 2 was recommended by civilian practitioners actively flying with the product.

Methods

This mixed-methods descriptive pilot study sought to evaluate the feasibility of high noise stethoscope technology in a simulated ERC environment. This study was approved by the Air Force Research Laboratory Institutional Review Board (IRB). A pilot study was necessary to estimate the sample size and evaluate if the devices could function in a simulated high noise military environment.[11] A simulated C-130 training platform was accessed at Wright-Patterson Air Force Base School of Aerospace Medicine, Fairborn, OH.

With device 1, before data collection, the research team received comprehensive, mandatory device training conducted by the device developer. The standardized training session included video training, discussions between trainers and the research team, and hands-on practice with human volunteers. An equivalent training session for device 2 was not provided by the device developer. This training was not provided because of the intuitive nature of the second device and its resemblance to a traditional stethoscope; however, the research team was provided with a user manual for the device. Upon completion of the training session for device 1, participants were provided with a draft questionnaire tool developed by the research team. This draft questionnaire was developed by modifying qualitative assessment questionnaires from previous studies.[2] Additional modifications to the questionnaire were made based on recommendations during the research team's training session. A cardiac and thoracic figure was included on each page of the questionnaire to standardize auscultation sites within subjects. The final questionnaire was reviewed by experts in AE and survey tool development and PhD researchers for added validity.

Participant training occurred in the same format as the research team training. Ten AE participants were provided with a 90-minute training session on device 1 conducted by the research team before data collection. Training sessions were conducted in 2-person class sessions. Each participant was given a kit containing everything needed for training and the use of device 1. The training session was composed of a verbal introduction to the study, a PowerPoint (Microsoft, Redmond, WA) presentation on the device, a training video provided in the device kit, a 30-minute practice session with the device on 2 human volunteers (1 man and 1 woman), and a review of the questionnaire.

With device 2, before data collection, 10 AE participants were again provided with a training session. The training session for device 2 was not as extensive as the training for device 1 because of the previously detailed simplicity of device 2. This training session was composed of a verbal introduction to the study, an introduction to device 2, and a review of the questionnaire; video trainings for this device were not required or performed. Participants were then able to practice on 2 human volunteers (1 man and 1 woman) in a classroom setting. Research team members were available to answer any questions during the practice session.

With both devices, once AE participants were comfortable with the use of the device, the researchers, human volunteers, and participants proceeded to the C-130 aircraft simulator for data collection. This aircraft simulator is rated for daily use; as such, it is not capable of replicating the exact noise levels that would be encountered in the flight environment because of occupational health requirements. The simulated environment is also not an altitude chamber nor does it include a shaker table; this prevents direct replication of several stressors encountered in the actual flight environment. The C-130 aircraft simulator was retrofitted with 2 patient litters in the middle of the airframe, with each human volunteer laying in the supine position on a litter. The volunteers were oriented with their heads toward the aft of the airframe. Participants used the communications earplugs (CEPs) supplied with device 1 along with their own military-issued David Clark (Worcester, MA) or Bose A20 (Framingham, MA) headsets overtop of the CEPs when auscultating using

device 1. In addition, this method was used for those having David Clark headsets when testing device 2, but those having Bose A20 headsets plugged directly into the adapter on the device to the communication system in the headset, avoiding the use of CEPs for device 2 with the Bose A20 headsets. All military providers select and are issued their preferred headsets based on their preference upon entering the AE career field.

Participants in this study were asked to complete cardiopulmonary assessments on both the male and female human volunteers in a simulated C-130 environment. Participants were instructed to auscultate using a comfortable volume level of the device that was loud enough for them to hear heart and lung sounds but was not too loud to cause discomfort. Cardiac assessment was completed in the 5 traditional anterior auscultation regions including aortic, pulmonic, Erb's point, tricuspid, and mitral regions. Pulmonary assessments were completed in the 16 traditional auscultation regions on the anterior and posterior surfaces.[12] Upon completing assessments on the male and female volunteers, participants provided quantitative and qualitative feedback pertaining to questions such as the device's durability, sound quality and volume, and applicability to the ERC environment.

Noise levels in the simulated environment were not recorded during data collection with device 1. Based on recommendations from the evaluation of device 1, noise levels in the simulated environment were recorded during data collection with device 2 with a G-4 type 2250 sound level meter manufactured by Brüel and Kjñr (Nñrum, Denmark).[13] Noise measurements were taken by a member of the study team in the simulated noise environment while standing between the 2 patient litters and in the classroom during the subjects' practice time near the auscultation area before data collection. The same simulated aircraft was used for the evaluation of both devices.

Quantitative data were analyzed using SPSS Statistics for Windows Version 22.0 (IBM Corp, Armonk, NY). Questions were rated using a Likert scale, and nonparametric statistics were conducted to analyze ordinal data. Participants rated their ability to auscultate at the standardized locations using a Likert scale ranging from 1 to 5 (1, unable to hear; 2, poor; 3, fair; 4, good; and 5, excellent). With device 1, these ratings were given for both the acoustic and Doppler modes. For both devices and all analyses, a P value $< .05$ was considered to be statistically significant, and the exact values were reported.

Qualitative methods were used to highlight key themes in the open-ended responses on the participants' perceived usefulness of the device. A typology method was chosen in which the goal was to develop a set of related, but distinct, categories within a phenomenon.[13] The typology analysis was conducted with the following steps: 1) identify an organizing framework, 2) identify a source of commonality and variation that occurs in a data set, 3) look within these areas of commonality or variation for similarities and differences, and 4) look at similarities and differences to reconstruct into types or model cases.[14] The analysis was conducted by the research team, and opposing analysis was discussed until consensus was reached among the research team.

Results

IRB determination of nonhuman use was obtained from the Air Force Research Laboratory IRB. Demographic information of participants was not collected. Participants consisted of 20 AE personnel, which included recruiting from a pool of physicians, nurses, and medical technician military providers. Some, but not all, participants volunteered to complete evaluations on both devices. The 2 devices were evaluated approximately 1 year apart (Table 1). The time gap in device evaluations results

Table 1
Comparison of Devices 1 and 2

	Device 1				Device 2	
	Acoustic Mode		Doppler Mode			
Region	Male Median [Q1, Q3]	Female Median [Q1, Q3]	Male Median [Q1, Q3]	Female Median [Q1, Q3]	Male Median [Q1, Q3]	Female Median [Q1, Q3]
Cardiac						
Spot 1	1 [1, 2]	1 [1, 1]	1 [1, 2]	1 [1, 4]	2.5 [2, 3.25]	3.5 [2.75, 4.25]
Spot 2	1 [1, 1.25]	1 [1, 2]	1 [1, 3]	4 [1.5, 4]	3 [2, 4]	4 [3.75, 4.25]
Spot 3	1 [1, 1.25]	1 [1, 1.25]	1 [1, 3]	3 [3, 4.5]	3 [2, 4]	4 [3, 4.25]
Spot 4	1 [1, 3]	1 [1, 2]	4 [1.75, 4.25]	4 [2.5, 5]	3 [2, 3.25]	3 [2, 4]
Spot 5	2 [1, 3]	1 [1, 1.25]	1.5 [1, 4]	4 [1.5, 4]	2.5 [2, 4]	3.5 [1.75, 4]
Pulmonary						
Spot 1	1 [1, 1.25]	1 [1, 2.25]	1 [1, 2]	1 [1, 1.25]	3 [2, 4]	3 [3, 4]
Spot 2	1 [1, 1.25]	1 [1, 2.25]	1 [1, 1.25]	1 [1, 1.25]	3 [2, 4]	3 [3, 4]
Spot 3	1 [1, 3]	1.5 [1, 2.25]	1 [1, 1.25]	1 [1, 1.25]	3 [2, 4]	4 [3, 4.25]
Spot 4	1 [1, 3]	1 [1, 3]	1 [1, 2]	1 [1, 2]	3 [2.75, 4]	4 [3, 4.25]
Spot 5	1 [1, 3]	1 [1, 2]	1 [1, 2]	1 [1, 3.25]	3 [2.75, 4]	4 [2.75, 4]
Spot 6	1 [1, 3]	1 [1, 2]	1 [1, 1]	1 [1, 3.25]	3 [2.75, 4]	4 [2.75, 4]
Spot 7	1 [1, 2.25]	1 [1, 2]	1.5 [1, 3]	2 [1, 3.25]	3 [2, 4]	4 [2.75, 5]
Spot 8	1 [1, 2.25]	1 [1,2]	1.5 [1, 3]	2 [1, 3.25]	3 [2, 4]	4 [2.75, 5]
Spot 9	1 [1, 2]	1 [1, 1]	1 [1, 1]	1 [1, 1]	3 [2, 4.25]	3 [3, 4.25]
Spot 10	1 [1, 2]	1 [1, 1]	1 [1, 1]	1 [1, 1]	3 [2, 4.25]	3 [3, 4.25]
Spot 11	1 [1, 2]	1 [1, 2.5]	1 [1, 1.25]	1 [1, 2]	3 [2, 4.25]	3 [3, 4]
Spot 12	1 [1, 2]	1 [1, 2.25]	1 [1, 1.25]	1 [1, 2]	3 [2.75, 4.25]	3 [3, 4]
Spot 13	1 [1, 2.25]	1.5 [1, 3.25]	1 [1, 2.25]	1 [1, 2]	3.5 [2.75, 5]	4 [3, 5]
Spot 14	1 [1, 2.25]	1.5 [1, 3]	1 [1, 2.25]	1 [1, 2]	3.5 [2.75, 5]	4 [3, 5]
Spot 15	1 [1, 2.25]	1 [1, 2]	1 [1, 3]	1 [1, 3]	4 [2, 5]	4 [2, 5]
Spot 16	1 [1, 2.25]	1 [1, 2]	1 [1, 3]	1 [1, 3]	4 [2, 5]	4 [2, 5]
Confidence in using mode to auscultate	1.5 [1, 3]	1 [1, 2]	2 [1.5, 2.5]	2 [2, 3]	3.5 [3.5, 4.25]	
Ease of using	2 [1, 3.5]	2 [1, 4]	2 [1.5, 3.5]	2 [1, 3]	4 [3, 4.25]	
Sound quality	2 [1, 2.25]	2 [1, 2]	2 [1.5, 4]	3 [1, 3]	4 [3.5, 4]	
Sound volume	3.5 [1, 4]	3 [1, 5]	3 [2, 4]	4 [1, 4]	4 [4, 5]	
Applicability to AE	1.5 [1, 2]	1 [1, 2]	2 [1.5, 4]	2 [1, 3]	4 [4, 4.5]	

AE = air medical evacuation; Q1 = quartile 1; Q3, quartile 3.

from the evaluation of device 2 being a follow-on to the original study aimed at the evaluation of device 1. During data collection with device 1, the average day noise level was an estimated 90.7 dBA acquired from a previous occupational health assessment (Memorandum. Subject: noise dosimetry survey. Aeromedical Evacuation Training Unit 817A; September 30, 2014), not measured directly by the research team. For device 2, a baseline noise level was collected in the classroom, and the average noise level was 87.3 dBA (range = 42.9-103.2). The higher ranges possibly reflect participants' discussion in the room and their distance from the device itself. During data collection with device 2 in the simulated C-130 environment, the average noise level was measured at 85.9 dBA (range = 40.1-109.6). Noise was measured at baseline and every 5 minutes during the assessment.

Device 1

Initial testing and questionnaire feedback from device 1 provided valuable insight about the feasibility of device 1 in a simulated ERC environment. Participants reported that with the acoustic mode of the device, for both the male and female volunteer, they were unable to hear both cardiac and pulmonary sounds. Participants had similar results when making use of the Doppler mode of the device; however, participants did report that select spots were rated higher for auscultation than others with the Doppler mode. On the female volunteer, cardiac assessment of spots 2, 4, and 5 was rated higher than spots 1 and 3. On the male volunteer, cardiac assessment was rated higher at spot 4. Statistical analysis found that the differences between the acoustic and Doppler modes of the device were statistically significant (data not shown). The quantitative feedback for the device was mirrored in the qualitative feedback provided by the participants.

The open-ended responses highlighted 5 major categories with several themes for the device. These categories were mechanics of the device, training, current practice, acoustics, and usefulness. Within these categories, themes relating to the device were determined. These themes highlighted, much like the quantitative responses, the difficulty providers perceived while using the device, as well as the inability to identify heart and lung sounds. Providers felt there was too much Doppler content included in the training session, and when looking at the usefulness of the device, the ultrasound gel added another time-consuming and messy element to the device. Despite the in-depth training, participants reported that the amount of training provided was adequate to meet their needs.

Participants reported the perceived usefulness of the device as low, stating it was difficult to auscultate on the male and female volunteers. The open-ended responses on the questionnaire corroborate the quantitative data, with participants reporting certain spots being better for auscultation. Participants also reported that the ability to auscultate with the device was dependent on the skill level possessed by the provider. This sentiment was also present when looking at the device's acoustics. Participants reported that the capabilities varied with different individuals. Along with this, participants found that the noise canceling in the headsets needed improvement because background noise and vibration were picked up while attempting to auscultate in the simulated C-130 environment. This initial qualitative and quantitative feedback resulted in canceling further testing with the device.

Device 2

Initial testing with device 2 provided quantitative and qualitative feedback. Quantitative feedback showed more optimal results than the previous device, with all spots for auscultation being rated with at least fair quality. However, a large number of spots were perceived to be of good quality by participants. With this, participants rated the quality and volume of sounds heard by the device as good. Participants provided high ratings when evaluating the ease of using the device and its applicability to the AE environment. These quantitative results are mirrored by qualitative results obtained from the participants' open-ended

Table 2
Emerging Themes for Device 1 and Device 2

Category	Themes for Device 1	Themes for Device 2
Mechanics of device	Headset	Improve durability
	Placement of buttons	Size and location of buttons
	Rubber cover	Visual display
	Size	Means of securing/holding
	Extend marks	Tailored filters
	Device holder	
	Battery	
Training	Adequate amount	Adequate amount provided
	Too much Doppler content	Minimal training required
	More hands-on practice	
	Question and answer session helpful	
	Reword certain terms	
Current practice	No auscultation during flight	Pre- and postflight assessment
	Use other assessment techniques in flight	No auscultation during flight
	Outdated Doppler for fetal or peripheral tones	Other assessment techniques in flight
	Rely on nonauscultation equipment	
Acoustics	Improve noise canceling in headsets	Improve noise canceling in headsets
	Background noise	Background noise
	Increase volume	Vibration
	Vibration	Satisfactory sound quality
	Capabilities vary with varying individuals	Certain spots better for auscultation
Usefulness	Difficult to auscultate	Cardiopulmonary auscultation possible
	Dependent on skill level	Confidence in controlled environment
	Acuity of patient	Beneficial with minor modifications
	Certain spots better	Intuitive device
	Confidence in controlled environment	
	Beneficial with modifications	
	Time-consuming	

responses, especially in the categories of the device's mechanics and usefulness.

In evaluating the usefulness of the device, participants provided responses stating that cardiopulmonary auscultation was possible. Participants also felt that the device was intuitive to use, bearing resemblance to a traditional binaural stethoscope. Overall, it was felt that the device would be beneficial to the ERC environment with minor modifications to the mechanics of the device. Participants felt that the device would not be durable for the environment in which they work. Participants provided suggestions for improving this durability by securing the device with either a lanyard or some form of portable case. There were also suggestions of improving the visual display on the device to make determining which filter is being used simpler. It was also suggested that the device have filters tailored to specific aircraft to further improve the device's acoustics. When evaluating the acoustics of the device, participants provided comments that mirrored the quantitative data. It was felt that the sound quality was satisfactory and that some locations were better for auscultation than others. However, providers did note that the device was still subject to background noise and vibration, something they felt could be remedied with filters built specifically for the airframe being used. Participants were also queried about the training provided before using the device for cardiopulmonary auscultation. Responses showed that the provided training was adequate and, again, highlighted that the device is intuitive for providers to use.

Overall

A comparison of devices 1 and 2 (Table 1) summarizes the quantitative findings for both of the devices that were evaluated. Cardiopulmonary auscultation locations were rated much higher for device 2 than device 1. This trend also holds true with the qualitative responses provided for both devices (Table 2). Despite the 2 devices having significantly different ratings, the qualitative results did show similarities between the evaluated devices. These similarities are most noticeable when participants were describing their current auscultation practices. With both of the devices, AE providers reported that they do not have a reliable means of performing cardiopulmonary auscultation during flight. Instead, if auscultation is to be performed, it is done in the pre- and postflight stages when ambient noise is lower than during flight. During flight, participants reported that they are reliant on nonauscultation assessment techniques.

Discussion

This study aimed to investigate the applicability and usability of stethoscope technology for AE/CCAT providers through the assessment of 2 devices in a simulated flight environment. Currently, AE providers have limited assessment capabilities because of the high ambient noise present in the ERC environment. With device 1, providers reported Doppler audible sounds were heard more than those in the acoustic mode. AE providers reported minimal scores in response to their ability to hear heart and lung sounds in the simulated C-130 environment with device 1. In this same device, it is notable that the cardiopulmonary sounds on the female volunteer were more audible than those on the male volunteer. This may be a result of the increased volume of subcutaneous tissue around the thorax area present in the female volunteer, allowing for better transmission of ultrasound waves. In a previous study using device 1, the mean ratings at various anatomic positions for cardiopulmonary auscultation in the acoustic mode were at least “fair.” The same ratings were given for auscultation in the Doppler mode, with clinical use ranging between 90 and 110 dB, respectively.[2] This previous study was conducted in an acoustic reverberation chamber containing a large rotating diffuser to prevent the formation of acoustic standing waves, a smaller environment than the C-130 simulator used for this study. Also, unlike the study conducted by Gaydos et al,[2] individuals in the current study made use of CEPs with either the David Clark or the Bose A20 headsets overtop of the CEPs when they were auscultating using device 1. However, the previously referenced study had device 1 interfaced directly into the helmet system for additional hearing protection and increased auscultation ability. These factors may have resulted in obtaining results contradictory to those in previous studies.

The results from device 2 showed much higher ratings than those of device 1. These findings show a potential materiel solution in the form of a novel electronic stethoscope that mitigates the increased noise associated with the ERC environment. Additionally, the findings from device 2 will result in future testing of the device in the C-130 and HH-60 aircraft during flight to determine the usability of the device in an operational environment. Further research may also need to be conducted with device 2 to ensure its applicability to an ERC environment and the impact of vibration through the provider and the patient on the sound quality. This research may also include the testing of nonstandardized patients, integrating existing sound libraries to compare cardiopulmonary sounds, and enabling the transmission of audio files to geographically separated providers for telemedicine.

Participants also reported that device modifications could be made to both of the devices. In the case of device 2, 1 suggested major modification was to tailor filters to specific aircraft noises (eg, implementing a filter that was unique to the C-130 or C-17 environment). In the current study, participating AE providers reported the need for device 1 to be smaller. However, this contradicts a previous study that evaluated device 1 in which participants reported a need for the device to be larger.[2]

It is evident that future studies need to be conducted with stethoscope technology specifically developed for high noise environments because of the austere environments present in ERC. In the typical civilian health care environment, a conventional stethoscope can typically be used for auscultation; this is not commonplace in AE. This study has shown potential challenges AE providers encounter during ERC in performing cardiopulmonary auscultation. Results have explored potential solutions to mitigate the high noise present in an ERC environment with modifications to current commercial off-the-shelf products. Currently, technology to aid in auscultation that is available to AE providers has limited applicability in an ERC environment because of the high noise and additional stresses of flight rendering the technology virtually useless. Lacking the ability to perform cardiopulmonary and other body system auscultation has the potential to be detrimental for optimal care during ERC transport. Future research will aim to provide ERC caregivers with a reliable means of auscultating in high noise austere environments.

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