



UNITED STATES ARMY AEROMEDICAL RESEARCH LABORATORY

Pilot Evaluation of the Safe Transport and Evacuation Protocol System (STEPS) in a UH-60 Simulator

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14. ABSTRACT The objective of this work was to evaluate the use of a proof-of-concept system, the Safe Transport and Evacuation Protocol System (STEPS), that presents flight restrictions to pilots compared to the current standard of verbal guidance from an onboard medic. Five U.S. Army UH-60M rated aviators completed simulated flights where they received flight restrictions either through a visual pilot aid or from a medic over the intercommunication system. While both configurations yielded 100% application accuracy and clinically insignificant differences, the STEPS configuration resulted in slightly longer average reaction times (13 vs. 7 seconds) and average application times (10 vs. 6 seconds) compared to the medic configuration, likely due to the partially obscured view of the pilot aid. Although subjects rated the medic configuration as more helpful and trustworthy, they recognized the operational utility of STEPS and recommended interface visibility improvements. The findings of this study help to inform the needed design modification for the continued development of STEPS while also highlighting opportunities for integration with autonomous platforms and unmanned aerial systems.					
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Summary

Introduction: Medical evacuation (MEDEVAC) missions require exceptional care to be delivered to patients in a variety of unique and challenging conditions, which may be less than optimal for patient and medical supply transport. Prior to transport, a provider may prescribe a patient certain flight prescriptions, such as a cabin altitude restriction, specific cabin temperature, etc. Currently, there are limited procedures in place to dynamically adjust these flight restrictions based on patient injuries or status during flight. One method to address this gap is the use of real-time data from patients and the cabin environment to generate flight restrictions dynamically and provide them to pilots or the onboard mission planning system during MEDEVAC operations.

Materials and Methods: The objective of this work was to evaluate the use of a proof-of-concept system, the Safe Transport and Evacuation Protocol System (STEPS), that produced and presented flight restrictions to pilots compared to the current standard of verbal guidance from a medic. The subject population included five U.S. Army UH-60M rated aviators. Subjects completed two 15-minute simulated flights, during which flight restrictions were presented to them visually through the pilot aid or verbally from a medic on the intercommunication set. Reaction time, application time, application success, and application accuracy were compared between subjects. Additionally, Likert ratings and subjective feedback were collected from the subjects.

Results: The average reaction time was greater during the STEPS configuration for subjects 1, 3, 4 and 5, while subject 2 produced a greater reaction time during the medic configuration. The overall average reaction time for STEPS was 13 seconds, while for the medic configuration it was 7 seconds. Application time, which describes the interval between the subject's initial acknowledgment of a restriction and the relay of the information to the pilot-in-command (PC), was greater for all subjects during the STEPS configuration compared to the medic configuration. Across all subjects, the average application time was 10 seconds for the STEPS configuration and 6 seconds for the medic configuration. All subjects successfully and accurately applied the flight restrictions to the PC. All subjects rated the medic's guidance as more helpful and trustworthy than the STEPS guidance. Three subjects expressed a preference for the medic's guidance, with two subjects explaining part of the reason being that the pilot aid was out of view. On the other hand, one subject preferred the STEPS guidance and three subjects believed that STEPS could be a beneficial addition to the cockpit, pending certain modifications.

Discussion: Overall, the average reaction time was greater during the STEPS configuration compared to the medic configuration. This difference may be attributed to the placement of the pilot aid within the cockpit, which may have been obscured or difficult to see for subjects. A similar trend was observed in the application time; this delay may be attributed to the time required to process the visual alert. Despite these measured differences, both configurations yielded very fast overall reaction times. From a clinical standpoint, a difference of a few seconds is unlikely to be practically significant. In terms of subjective feedback, three of the five subjects expressed a preference for the medic's guidance, which could be a result of the pilot aid's location within the simulator. Two subjects stated that the pilot aid was out of view, making it easy to overlook flight restrictions. On the other hand, two subjects mentioned that the pilot aid provided a helpful visual reference to the restrictions during flight. A total of three subjects believed that STEPS could be a beneficial addition to the cockpit, pending certain modifications. Modifications such as the inclusion of an indicator light to increase pilot

awareness or integrating the pilot aid with the master warning caution panel were proposed.

Conclusion: The findings of this study provided the guidance necessary for the continued development of the STEPS. In the future, STEPS has the potential to integrate with unmanned aerial systems and in semi- and fully autonomous platforms. Future conflicts are expected to produce high volumes of severe casualties requiring transport. In conjunction with a lack of air superiority and the use of unconventional vehicles of opportunity, the relevance of STEPS and future capabilities to dynamically adjust flight restrictions to promote optimal patient outcomes will be critical.

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Introduction

Medical evacuation (MEDEVAC) missions require exceptional care to be delivered to patients in a variety of unique and challenging conditions. These conditions may be less than optimal for patient and medical supply transport. Patients are exposed to a variety of environmental factors that can induce physiological stress on the body, such as gravitational (G) forces, aircraft orientations, barometric pressure changes, decreases in atmospheric oxygen, exposures to extreme temperatures, decreases in atmospheric humidity, and mechanical vibrations and shocks. The primary concern for patients is how these factors may create a secondary insult to their injuries, potentially exacerbating their condition. Before a casualty is transported by the U.S. Air Force, a Theater Validating Flight Surgeon (TVFS) must deem the patient able to travel. The TVFS is also able to prescribe any flight restrictions such as cabin altitude restrictions, no stops, cabin temperature, and long, slow takeoffs and landings (Butler & Steinkraus, 2020). For tactical evacuation by rotary-wing aircraft, U.S. Army flight surgeons make similar recommendations to the flight crew. The goal of these restrictions is to improve patient outcomes.

Limited studies have been performed that investigate the health effects of these flight restrictions. Additionally, these restrictions are often prescribed before flight. There are few procedures in place to dynamically adjust these flight restrictions based on patient injuries or status during flight. Any adjustments made in flight are often the result of a provider suspecting a specific condition or observing a decline in the patient status and directly communicating with the pilots to alter a flight parameter. However, pilots and flight crew routinely prioritize mission, enemy, terrain, troops, time available, and civil considerations (METT-TC) over medical considerations.

Although aircraft and mission safety are critical factors during MEDEVAC operations, this strict adherence to guidance introduces an opening for a potential solution, i.e., acute adjustments to flight parameters that do not jeopardize METT-TC. There are no universal guidelines on how to restrict flight profiles to safeguard the patient condition, only generalized recommendations exist. As mentioned previously, a TVFS (Air Force), or flight surgeon (Army) must deem the patient fit to travel and are able to prescribe any flight restrictions that may be necessary. In the future, providers may struggle with this guidance as casualties requiring transport are predicted to increase in number and severity. There is currently no automated method of generating flight restrictions dynamically, using factors such as patient injury type, patient status, cabin environment, etc. One method to address this gap is the use of real-time physiological monitoring data from patients as well as cabin environment measures to generate recommended flight restrictions and provide them to pilots or the onboard mission planning system during MEDEVAC operations.

Using lessons learned from the ongoing conflict related to the 2022 Russian invasion of Ukraine as an indicator, it is likely that future U.S. Army MEDEVAC operations during large-scale combat operations (LSCOs) will require a greater number of casualties being transported, with an increase in injury severity (Epstein et al., 2023). It is likely that there will be a greater number of casualties than the capacity of dedicated medical mission vehicles, creating a need for non-conventional air and ground vehicles to be used to transport casualties and medical supplies. Fully or semi-autonomous vehicles may be utilized in these scenarios, as stated in the Army

Medical Modernization Strategy, “Unmanned aerial systems and unmanned ground vehicles will autonomously transport casualties, execute medical resupply, and conduct applicable operational public health tasks” (U.S. Army Futures Command, 2022, pp. 13). In anticipation of future LSCO, considerable research is being conducted on autonomous solutions for casualty care and transport. In 2012, the North Atlantic Treaty Organization (NATO) published a document outlining the use of unmanned aerial vehicles (UAVs) for casualty evacuation (CASEVAC) (NATO, 2012). This publication began outlining a variety of safety parameters (e.g., vibration levels, acceleration, noise levels, etc.) that should be considered when evacuating casualties using UAVs. A 2024 review discussing the modernization in the design, development, limitations, and challenges of implementing autonomous systems during CASEVAC reasserted these parameters discussed in the 2012 NATO publication (Nichols, 2024). This review also discussed the integration of medical platforms within the autonomous systems, stating that improved monitoring of patient status will be needed.

While there have been clear advancements in the development of these autonomous platforms, a critical gap still exists in dynamically adjusting flight profiles to prevent exacerbation of patient conditions. Addressing this gap is crucial for the safe and effective implementation of autonomous systems in future MEDEVAC and CASEVAC operations. This will be particularly important with the expected increase in casualty burden of LSCO. One potential solution that the U.S. Army Aeromedical Research Laboratory (USAARL) has been working on is known as the Safe Transport and Evacuation Protocol System (STEPS). This proof-of-concept system is able to successfully collect static patient information, monitor real-time patient vitals from an emulator, and receive flight data from a simulated aircraft. The STEPS translates patient injury data automatically into real-time flight restrictions using a central decision-making algorithm. The objective of this work was to evaluate the use of an automated flight restriction system, the STEPS, compared to the current standard of verbal guidance from a medic.

Research Questions

- *Research Question 1:* How rapidly do pilots acknowledge and apply the automated flight constraint alerts provided by the STEPS pilot aid during the simulated flights compared to flight constraints recommended by a Medic?
- *Research Question 2:* To what extent does using the STEPS pilot aid influence pilot application of the flight constraints compared to standard medic guidance?
- *Research Question 3:* What are the pilots’ perceptions of the STEPS pilot aid’s utility in the mission? Specifically, how helpful and important do they find the system for maintaining safe MEDEVAC/patient travel flight conditions, and how much do they trust the system’s alerts?
- *Research Question 4:* After experiencing both conditions, do pilots prefer receiving flight constraint guidance from the STEPS automated alert system or from a medic?

Materials

The purpose of the pilot aid was to visually alert the pilots of a rotary-wing aircraft that a flight restriction has been recommended by the STEPS module. The pilot aid was placed toward the bottom right of the center console of the Cockpit and Academics Procedural Tool – Enhanced, Visual Capable System (CAPT-E VCS) simulator (Figure 1).



Figure 1. The STEPS pilot aid (outlined in red) installed within CAPT-E VCS simulator.

When a flight restriction was generated, the corresponding light emitting diode (LED) indicator button entered a flashing state. Simultaneously, the associated flight parameter was displayed on the screen, providing the pilot with information regarding the restriction's magnitude and direction, and whether the value was a maximum or minimum. To maximize visibility, active restrictions were highlighted in red (Figure 2, left). To acknowledge the restriction, the pilot pressed the associated LED button, terminating the LED's flashing sequence. The flight restriction remained on the screen but appeared on a black background with white text (Figure 2, right).



Figure 2. The pilot aid displaying restrictions (left, active restrictions; right, acknowledged restrictions).

The physical pilot aid prototype was built around a Raspberry Pi (RPi) 5, an affordable, commercially available single-board computer selected for its processing power and compact form factor. The schematic of the device is shown in Figure 3. The circuit utilized a number of additional electronic components which are detailed in Table 1.

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Table 1. Pilot Aid – Part List

Part Name	Manufacturer	Specifications
Raspberry Pi Model 5	Raspberry Pi	• 2.4 Gigahertz (GHz) quad-core • 2.4 GHz and 5.0 GHz Wi-Fi • Gigabit ethernet • 8 Gigabyte (GB) SD RAM
LED push button	Woljay	• Type: momentary, 1 normally open, 1 normally closed • 5 pin • DC 24 volts (V)
Resistor	Not applicable (N/A)	• 10 kilohm
Transistor	N/A	• PN2222A transistor
Power supply module	minidodoca	• MB-102 breadboard power supply module • 3.3V, 5V
Display screen	Hoysond	• 3.5-inch Raspberry Pi Display • 320×480 resolution
Face plate	In-house fabrication shop	• Overall dimensions: 6.75 x 5.75 x 0.125 inches • Material: aluminum
Display housing	In-house fabrication shop	• Three-dimensionally (3D) printed
Semi-enclosed mounting kit for Raspberry Pi	OONO	• Aluminum plate • Nylon standoffs, spacers and screws
Cooling fan	iUniker	• Aluminum heatsink and 3510 cooling fan • 1.8 Watts
Power supply	CanaKit	• Power supply for Raspberry Pi – Universal serial bus (USB)-C • 45 Watts
Secure digital card	SanDisk	• 128 GB

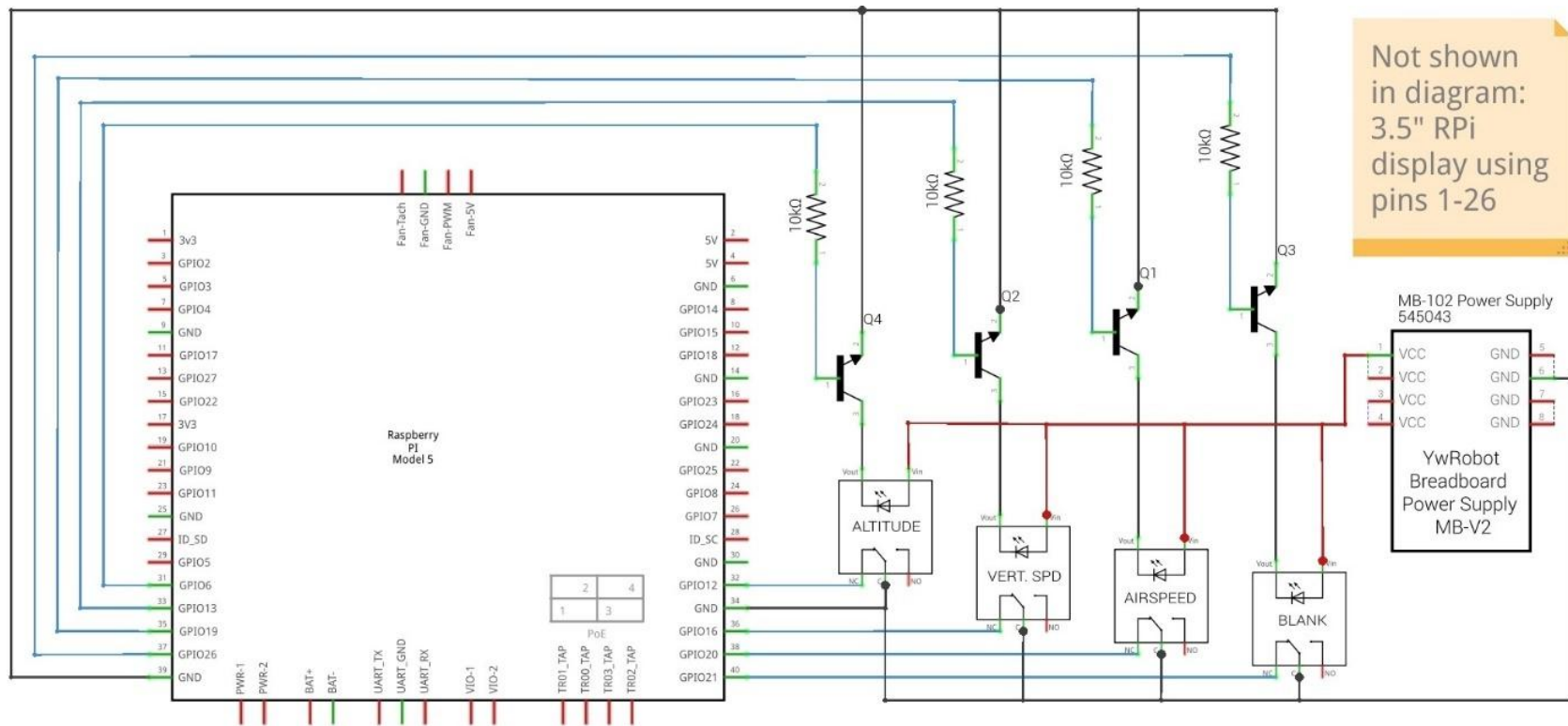


Figure 3. The schematic diagram illustrates the internal components of the pilot aid.

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The static data of the simulated casualty was entered into the STEPS module (Figure 4). The design and functionality of the STEPS module are detailed further in a previous technical report published by USAARL (Enzor, Black, et al., 2026).

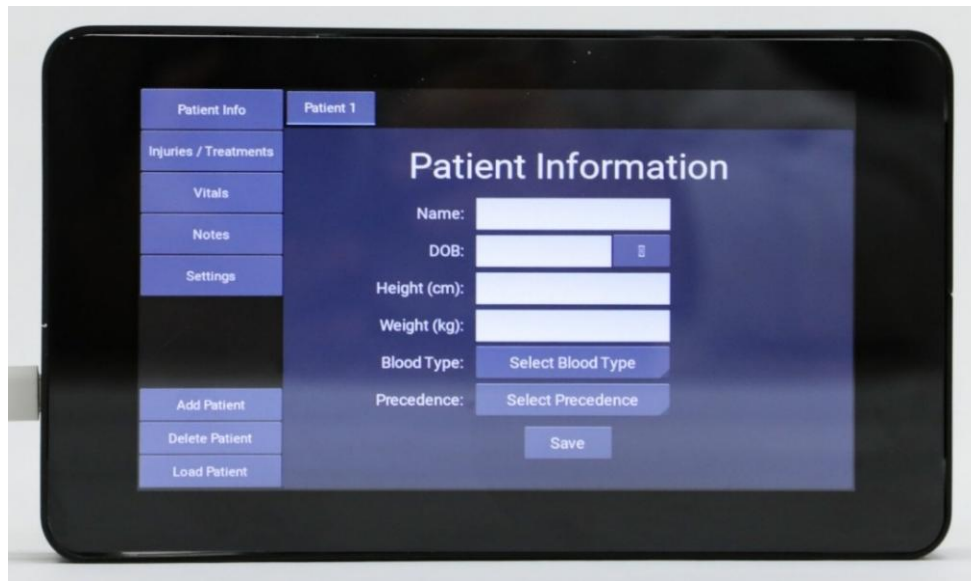


Figure 4. The benchtop prototype of the STEPS module is shown.

This static data collected by the STEPS module consists of parameters including name, height, weight, injury location and type, treatments performed, medications administered, and more. To simulate real-time vitals, the study team designed and fabricated a custom device (Figure 5). This device enabled the manipulation of five vital signs during testing: heart rate, blood pressure, respiration rate, oxygen saturation, and body temperature.



Figure 5. The physical prototype of the patient emulator is shown.

Methods

Subjects, Inclusion, & Exclusion Criteria

The subject population included one National Guard and four U.S. Army Active-Duty UH-60M rated aviators. Prior to their involvement in the study, all subjects received a briefing from the principal investigator and agreed to participate in writing. Eligible subjects included Active-Duty or National Guard personnel rated on the UH-60M Black Hawk. Additionally, subjects were required to be at least 18 years old. They were in good health and cleared for flight simulator use, as indicated with an approved DD Form 2292. Subjects were able to follow verbal and written instructions in English. Additionally, subjects were required to agree to video and sound recordings. Subjects were excluded from this study if they had taken any medications that may induce drowsiness, such as antihistamines. Furthermore, subjects were excluded if they had consumed alcohol or sedatives in the 24 hours preceding data collection.

Study Design & Procedures

This study evaluated a proof-of-concept system that produced flight restrictions to pilots. Subjects completed two 15-minute simulated flights during which flight restrictions were presented to them through the pilot aid (Figure 6), or verbally from a medic over the intercommunication set (ICS) as a control condition. Pre-planned patient injury profiles were created to standardize the restrictions provided in each condition, ensuring consistent and controlled scenarios. More information regarding these patient profiles can be found Table B1 located in Appendix B.



Figure 6. The pilot aid rests within a wooden stand.

Prior to data collection, subjects were asked to complete a demographic and personal history questionnaire, found in Appendix C. This questionnaire documented their age, rank, flight hours, deployment history, and more. After completion of the pre-test questionnaire, subjects were introduced to the USAARL research pilot with whom the subject completed the data collection. To ensure standardization across all flight conditions, a trained USAARL research pilot served as the pilot “on the controls” or pilot-in-command (PC) for each subject during all flight simulation activities. Subjects were required to wear a Head Gear Unit-56/Personal (HGU-56/P) (Army rotary-wing helmet) during testing as they would during normal flight operations.

The research pilot provided the subject with a pre-flight brief, which covered what was expected of them during data collection and how the flight restrictions would be provided in each configuration. During this brief, the subjects were shown an example of how the pilot aid would display real-time restrictions, how to acknowledge them, and how the flight medic would verbally communicate a restriction over the ICS. During the STEPS configurations, flight restrictions were delivered as numerical limits (e.g., ‘MAX 5000 feet [ft]’). In contrast, the flight medic provided more qualitative, general guidance to realistically simulate MEDEVAC operations. Additionally, subjects were permitted to interact with the medic for clarification. The general script used by the medic for each flight restriction is shown in Table 2.

Table 2. Script Used by Medic for Each Restriction Type

Restriction Type	STEPS (quantitative)	Medic (qualitative)
Altitude	MAX 5000 feet	“Let’s keep the altitude under 5000”
Vertical speed	MAX 1000 feet/minute	“Keep the climbs slow” or “Slow the rate of ascent”
Airspeed	MAX 120 knots	“Slow it back under 120 knots”
	MIN 120 knots	“We need to get there” or “Increase speed”

Each subject participated in two simulated 15-minute flights, one under each configuration (STEPS and medic). Each flight was designed to generate a moderate workload environment for the subject. Research pilots in the Flight Systems Branch (FSB) of USAARL designed the flight routes that were used during data collection. Two routes were created, termed MARS and CERUS; the routes were similar in terrain and difficulty. These routes were designed to challenge the potential flight restrictions presented to the subjects. During each simulated flight, one emergency procedure was triggered that required a response from the subject. These procedures were integrated by the research pilot during route design to increase the subject’s cognitive load and simulate realistic operational stress.

A total of four patient scenarios were used, and are referred to as Patient 1 (P1), P2, P3, and P4. Unique pairings using these four patients were used to create four unique profiles (A, B, C, and D), with each profile containing two patient scenarios. Table 3 shows the route order, configuration, and profile setup used to ensure that these factors were counterbalanced for each subject. The profiles were varied to ensure the subject did not receive a restriction from the same patient twice.

Table 3. Route, Configuration, Profile and Restriction Order

Subject (S) #	Route	Configuration	Profile	Patient Restriction Order
S1	MARS	STEPS	A	P1, P2
	CERUS	Medic	B	P3, P4
S2	MARS	Medic	C	P1, P4
	CERUS	STEPS	D	P2, P3
S3	CERUS	STEPS	A	P1, P2
	MARS	Medic	B	P3, P4
S4	CERUS	Medic	C	P1, P4
	MARS	STEPS	D	P2, P3
S5	MARS	STEPS	B	P3, P4
	CERUS	Medic	A	P1, P2

During each data collection run, two simulated patients were used. The patient profiles were loaded into the STEPS module prior to the start of data collection. During each flight, two sets of restrictions were presented to the subject. One set of restrictions contained two flight parameters, and the other contained one flight parameter. For example, one set of restrictions alerted the pilot to adjust their altitude and vertical speed, and the other set only alerted the pilot to one parameter, such as airspeed. The order of these sets of restrictions varied between subjects (Table 3, right column).

During data collection, the STEPS received data from the patient emulator and CAPT-E VCS. After completing each run, a comma-separated values (.CSV) file was exported. This .CSV file contained information regarding the patient (injuries, vitals, etc.) from STEPS and flight data from the simulator. The following flight parameters were collected: radar altitude, barometric altitude, indicated airspeed, rate of climb, latitude, and longitude. The data collected and exported in the .CSV file was used in the data analysis.

Data Analysis

Reaction time was measured as the time from restriction onset to when the subject acknowledged the presence of a restriction. Acknowledgment was achieved by pressing the associated button on the pilot aid, or through visual or verbal means, such as the subject stating they saw a restriction or by looking at the pilot aid. The .CSV file exported by STEPS displayed the time when the restriction was sent, as well as when a button on the pilot aid was pressed. Analysis of video and audio data was used to determine when the medic informed the pilot of a flight restriction and when it was acknowledged.

Additionally, the audio and video data were used to determine application time, which was the time between restriction acknowledgment to application (informing the PC of the restriction), application success, and application accuracy. Application success occurred when the subject effectively informed the PC of a flight restriction provided by either STEPS or the medic. This was a binary variable, categorized as either success or failure. Application accuracy, on the other hand, assessed whether the information conveyed by the subject aligned with the

flight restriction given. This was also a binary variable, classified as accurate or inaccurate. For instance, if the flight restriction advised the subject to remain below 5000 feet, but the subject instructed the PC to stay below 4,000 feet, the subject would have achieved application success while demonstrating application inaccuracy. Additionally, Likert scales assessing helpfulness and trustworthiness were included in the post-study questionnaire.

Results

Time Data

The average reaction time was greater during the STEPS configuration for subjects 1, 3, 4 and 5. Only subject 2 produced a faster average reaction time during the STEPS configuration. Overall, the average reaction time for STEPS was 13 seconds, while for the medic configuration it was 7 seconds. Figure 7 shows the average reaction time for each configuration and subject.

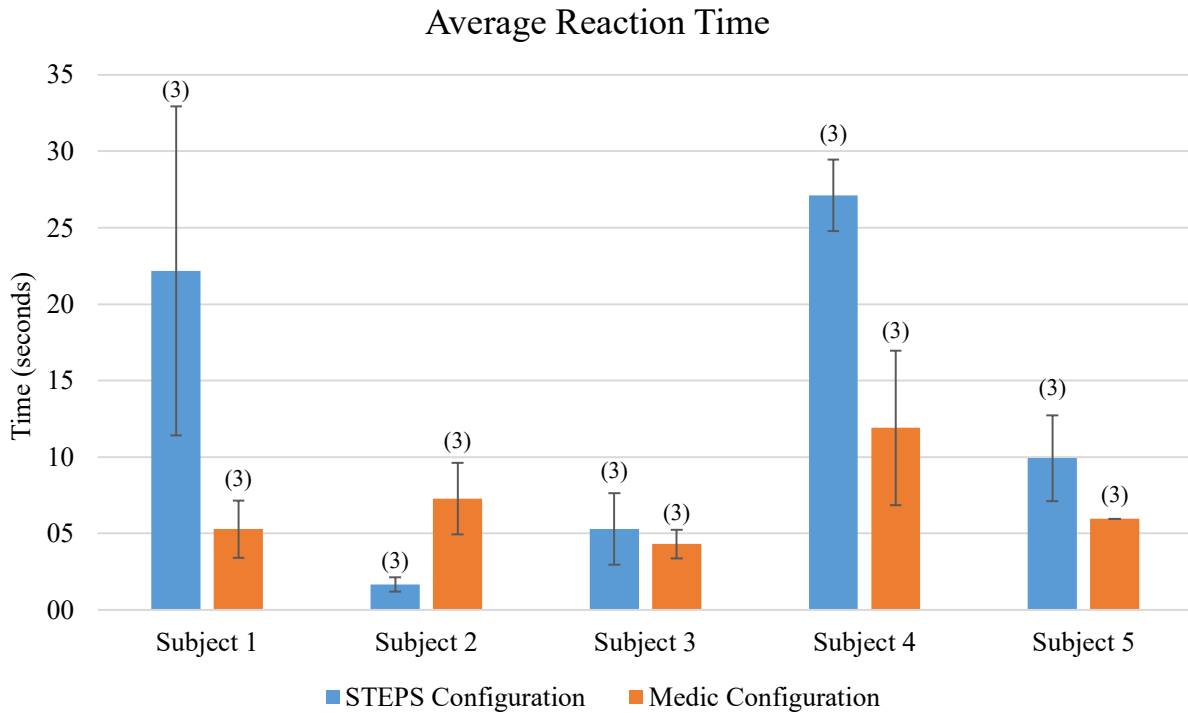


Figure 7. The average reaction time to flight restrictions between configurations and subjects is shown. Error bars represent one standard deviation within subject and configuration. The value in parentheses indicates the total number of alerts delivered per run (*n*).

For all subjects, application time was greater during the STEPS configuration compared to the medic configuration. Across all subjects, the average application time was 10 seconds for the STEPS configuration and 6 seconds for the medic configuration. The average application time for each configuration and subject is shown in Figure 8.

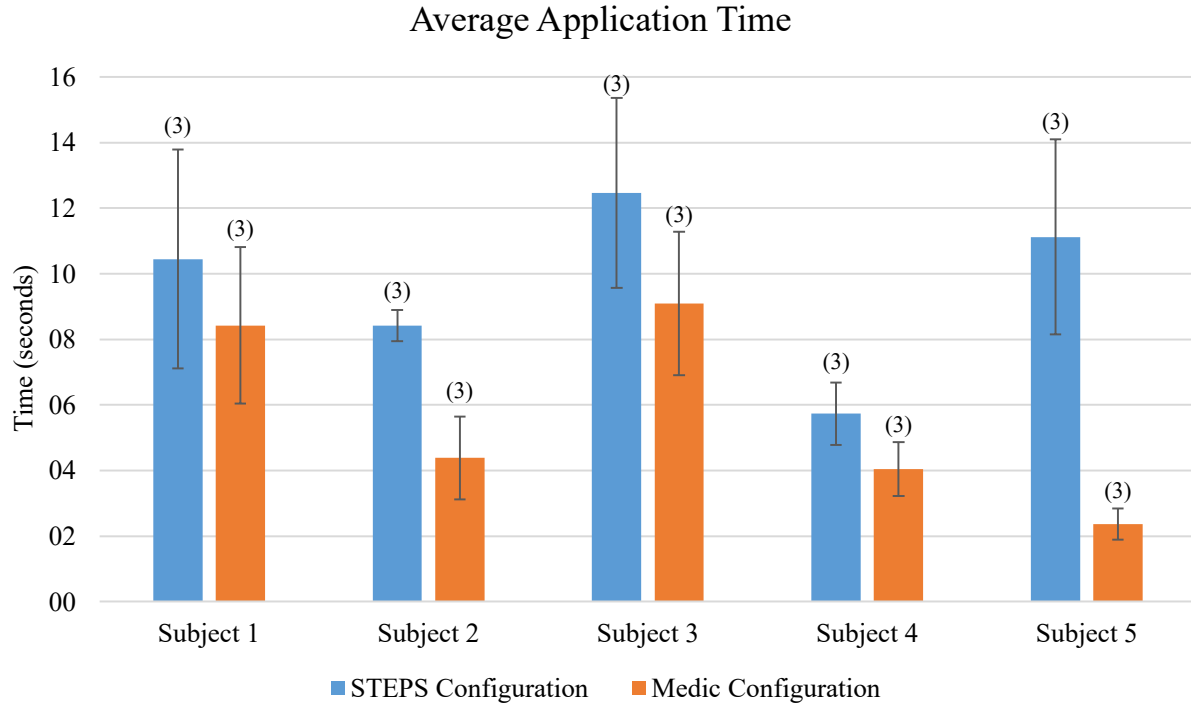


Figure 8. The average application time between configurations and subjects is shown. Error bars represent one standard deviation within subject and configuration. The value in parentheses indicates the total number of alerts delivered per run (n).

Application success occurred when the subject effectively informed the PC of a flight restriction provided by either the pilot aid or the medic. This was a binary variable, categorized as either success or failure. Application accuracy evaluated whether the information relayed by the subject matched the flight restriction given. This too was a binary variable, classified as accurate or inaccurate. Table 4 shows the application success and accuracy by subject and configuration. All subjects successfully and accurately applied the flight restrictions to the PC.

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Table 4. Application Success and Accuracy by Subject and Configuration

Subject #	Configuration	Application Success (Success/Failure)	Application Accuracy (Accurate/Inaccurate)
S1	STEPS	Success	Accurate
	Medic	Success	Accurate
S2	STEPS	Success	Accurate
	Medic	Success	Accurate
S3	STEPS	Success	Accurate
	Medic	Success	Accurate
S4	STEPS	Success	Accurate
	Medic	Success	Accurate
S5	STEPS	Success	Accurate
	Medic	Success	Accurate

Questionnaire Data

A post-test questionnaire was completed by the subject after completion of both simulated flights. This questionnaire can be found in Appendix B. Subjects were asked to answer the following questions on a scale from 1 to 5, where 1 indicated “not helpful at all,” a 3 meant “moderately helpful,” and a 5 denoted “very helpful.”

- How helpful did you find STEPS?
- How helpful did you find the medic’s guidance?

All subjects rated the medic’s guidance as more helpful than the STEPS guidance. The medic’s guidance never scored below a 4, which was the highest score for the STEPS guidance. The mean helpfulness score for STEPS was 3.4, while the mean score for the medic guidance was 4.6. The helpfulness scores are shown in Figure 9.

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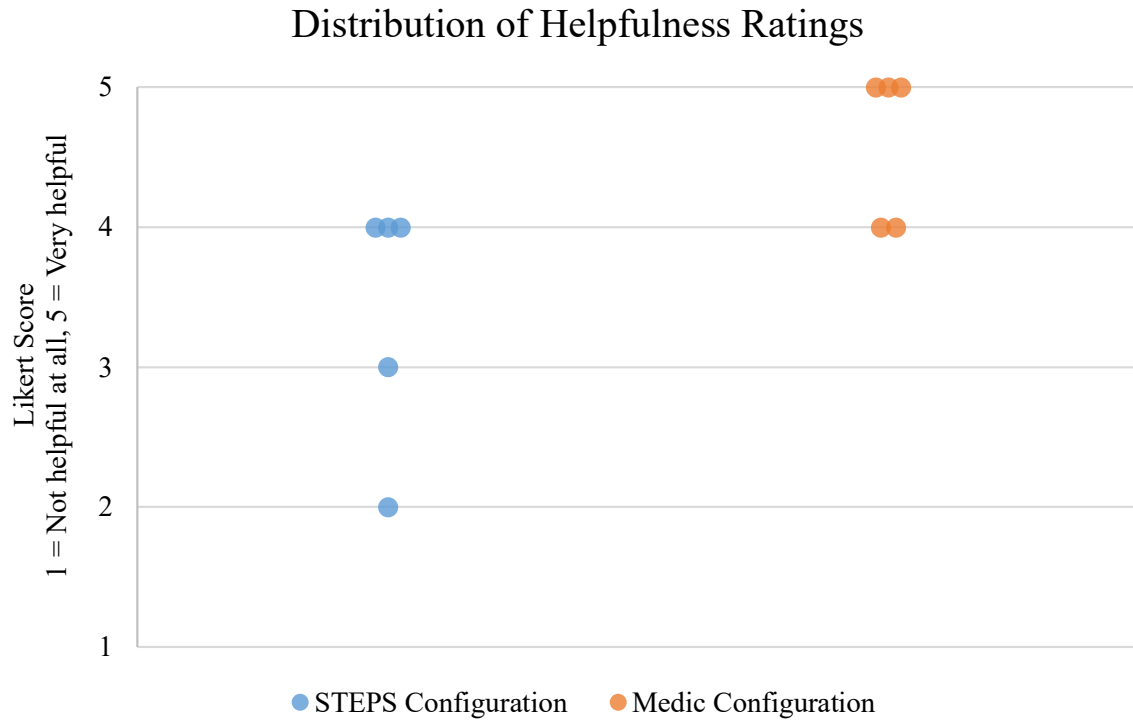


Figure 9. The helpfulness ratings were compared for both configurations ($n = 5$).

In addition to rating the helpfulness, subjects were also asked to rate the trustworthiness of the STEPS and medic guidance. The subjects responded to the following questions where 1 indicated “not trustworthy at all,” 3 represented “moderately trustworthy,” and 5 signified “very trustworthy.”

- How trustworthy were the STEPS recommendations?
- How trustworthy were the medic’s recommendations?

All subjects rated the medic’s guidance equal to or more trustworthy than the STEPS. The average trustworthiness score for STEPS was 3.4, and for the medic was 4.6. The trustworthiness ratings are shown in Figure 10.

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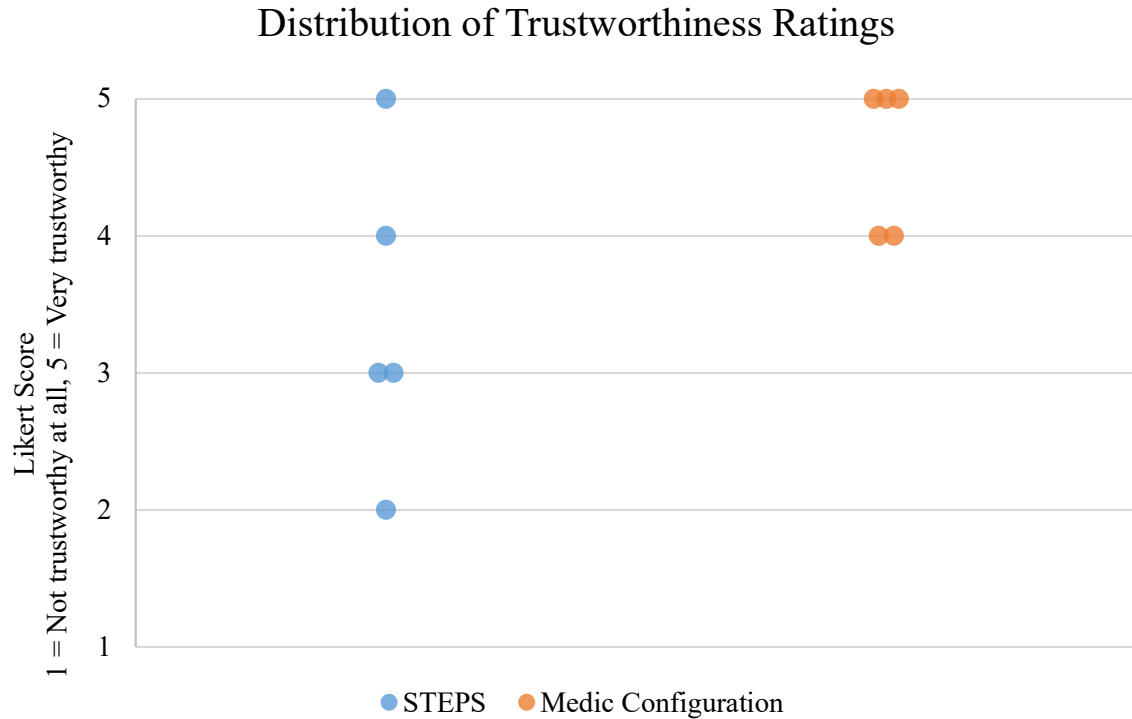


Figure 10. The trustworthiness ratings were compared for both configurations ($n = 5$).

In addition to the ratings question, the subjects were asked two open-ended questions, listed below:

- Did you prefer the guidance from the STEPS or the medic? Why?
- Do you think that the STEPS would be an important addition to the cockpit? Why or why not?

Three subjects expressed a preference for the medic's guidance, with two citing part of the reason being that the pilot aid was out of view. Another subject indicated a preference for the medic's guidance due to faster reception of verbal information. One subject stated they preferred the medic configuration because during the STEPS configuration it was difficult to adhere to the flight restriction and would have preferred being able to discuss other options with the medic. While subjects were permitted to interact with the medic for clarification or to discuss alternatives, no subjects explicitly requested a different flight profile. Instead, subjects typically acknowledged the medic's guidance and stated when a restriction would be difficult to meet while confirming they would attempt to comply. Only one subject asked for a specific value when the medic provided general guideline without a numerical limit. In contrast, one subject preferred the STEPS configuration due to it providing a visual reference in the cockpit. Lastly, one subject reported having no preference between STEPS and the medic configurations. Figure 11 summarizes the subject responses.

Guidance Delivery Preference

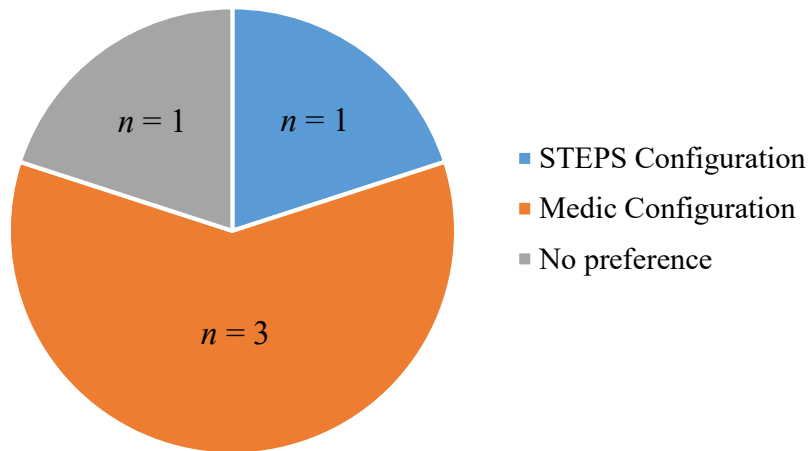


Figure 11. The subject responses of preferred method to receive flight restrictions were illustrated.

Three subjects believed that STEPS could be a beneficial addition to the cockpit, pending certain modifications. One subject proposed the inclusion of an indicator light to increase pilot awareness, while another suggested that STEPS be tied into the master warning caution panel. The subject that answered “maybe,” expressed concerns regarding how much they would trust a system to give real-time patient updates compared to a flight paramedic. Figure 12 summarizes the subjects’ responses.

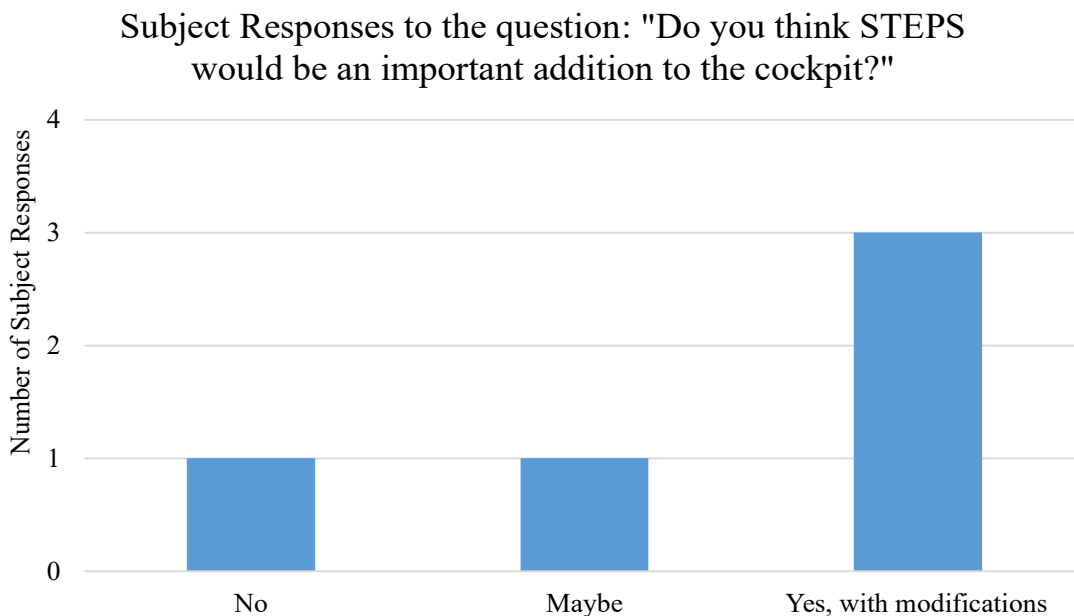


Figure 12. Subject responses to the question: “Do you think STEPS would be an important addition to the cockpit?” are summarized.

Discussion

Overall, the average reaction time was greater during the STEPS configuration compared to the medic configuration. This difference may be attributed to the location of the pilot aid within the cockpit, which was partially obscured or difficult for subjects to see. Two subjects stated that the location of the pilot aid was out of view, making it easy to overlook. In contrast, the medic's direct communication with the subjects likely contributed to a shorter average reaction time. The medic did not need to capture the subject's attention before delivering flight restrictions. A similar trend was observed in the application time, with the STEPS configuration having a greater average application time of 10 seconds, while the medic configuration averaged 6 seconds. This delay may be attributed to the time required to process the visual alert. In one instance, a subject visually acknowledged the restriction but waited for the PC to finish talking before relaying the information. Conversely, because the medic provided the restriction directly over the ICS, subjects often immediately repeated the verbal guidance ensuring the PC was aware. This eliminated the delays associated with processing and relaying the visual information in the STEPS configuration.

In both configurations, all subjects successfully and accurately conveyed the flight restrictions to the PC. However, subjects rated the medic's guidance as more helpful and more trustworthy than that of the STEPS. Notably, the trustworthiness ratings for STEPS exhibited a wider range of scores than the helpfulness ratings. This may be due to a varying level of trust in automated systems. One subject expressed specific concerns regarding their willingness to trust a system to provide real-time patient updates compared to a flight medic.

Three of the five subjects expressed a preference for the medic's guidance, citing two primary reasons. First, the physical placement of the pilot aid within the cockpit was partially obscured. One subject noted that the pilot aid was out of view, and another reported that their shoulder occasionally blocked the pilot aid. Second, the pilot aid lacked user interactivity. One subject noted that during the STEPS configuration, it was challenging to adhere to the flight restrictions and expressed a desire to discuss alternative options with the medic. During the data collection, most subjects typically did not ask for an alternative option from the medic, but rather acknowledged the medic's guidance, and stated when a restriction would be difficult to meet while confirming they would attempt to comply. To address the visibility issue, two subjects proposed potential solutions: one suggested the inclusion of an indicator light to increase pilot awareness, while the other recommended that the pilot aid be tied into the master warning caution panel. Conversely, two subjects stated that the pilot aid was useful as it provided a continuous visual reference to the restrictions during flight.

This study identified key areas for the continued development of the pilot aid, specifically highlighting the need to optimize its visibility and interactivity. Looking ahead, the STEPS has the potential to integrate within UAVs and autonomous platforms as a source of patient-specific safety limit inputs. With future conflicts expected to increase the number and severity of casualties requiring transport, particularly where air superiority is not guaranteed and vehicles of opportunity may be utilized, the capability to dynamically adjust flight parameters will be vital. The continued development of STEPS will address this capability gap, enabling real-time patient and environmental data to be transformed into flight restrictions that improve patient outcomes.

Limitations

Additional data was collected that is not presented in this report. The following flight parameters were collected: radar altitude, barometric altitude, indicated airspeed, rate of climb, latitude, and longitude. Due to the subject being the co-pilot or pilot “off the controls,” compliance with the flight restrictions through frequency counts of constraint violations were not examined. This variable was no longer applicable to the data analysis that was performed. The research team, along with the FSB at USAARL, made the decision for the subject to be the co-pilot to ensure they would have the ability to freely scan inside the cockpit during data collection.

Conclusion

This study confirmed the feasibility of automated flight restrictions but identified design limitations that must be addressed to optimize the end user’s performance and trust. These findings underscore the need for enhancements to the visibility and interactivity of the STEPS device, while also suggesting opportunities for future integration with UAVs and semi- or fully autonomous platforms. Furthermore, additional research into the integration of real-time patient data into medical transport is critical, particularly in an LSCO environment, where large numbers of patients will be transported using vehicles of opportunity.

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Appendix A. Acronyms and Abbreviations

BP	Blood Pressure
CAPT-E VCS	Cockpit and Academics Procedural Tool – Enhanced Visual Capable System
CASEVAC	Casualty Evacuation
CSV	Comma-Separated Values
FSB	Flight Systems Branch
G	Gravitational
GB	Gigabyte
GHz	Gigahertz
GSW	Gunshot Wound
HR	Heart Rate
ICS	Intercommunications Set
LED	Light Emitting Diode
LLE	Left Lower Extremity
LSCO	Large-Scale Combat Operations
MEDEVAC	Medical Evacuation
METT-TC	Mission, Enemy, Terrain, Troops – Time, Civilian considerations
mg	Milligram
mL	Milliliter
MOI	Mechanism of Injury
NATO	North Atlantic Treaty Organization
O ₂	Oxygen
P	Patient
PACER	Patient and Casualty Evacuation Research
PC	Pilot-in-Command
RLE	Right Lower Extremity
RPi	Raspberry Pi
RR	Respiration Rate
RUE	Right Upper Extremity
S	Subject
SpO ₂	Oxygen Saturation
STEPS	Safe Transport and Evacuation Protocol System
TBI	Traumatic Brain Injury
TBSA	Total Body Surface Area
Temp	Body Temperature
TVFS	Theater Validating Flight Surgeon
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
USB	Universal Serial Bus
USAARL	United States Army Aeromedical Research Laboratory
V	Volts
3D	Three-Dimensional

Appendix B. Patient Profiles

Table B1. Patient Profiles

Patient #	Vitals	MOI	Injury	Interventions
1	HR: 110 BP: 96/60 SpO ₂ : 94% RR: 18 Temp: 99°	GSW	Penetrating trauma to the chest	Chest seal, Ketamine (20 mg), supplemental O ₂
2	HR: 105 BP: 115/85 SpO ₂ : 94% RR: 15 Temp: 98°	Vehicle crash	Suspected right femur fracture	Ketamine (20 mg), RLE splint, supplemental O ₂
3	HR: 85 BP: 131/78 SpO ₂ : 94% RR: 14 Temp: 100.6°	Vehicle crash and fire	2 nd degree burns, maybe to chest, upper arm and neck area. (Around 16% TBSA), LLE femur fracture	Saline rinse, dressing place, 500 mL saline bag started by ground medic, Ketamine (20 mg), supplemental O ₂ , LLE splint
4	HR: 85 BP: 145/82 SpO ₂ : 97% RR: 16 Temp: 99.1°	Blast	LLE fractured fibula, open wound in the RUE, possible TBI. Unconscious on arrival	Ketamine (20 mg), LLE split, RUE pressure bandage, 3% saline, supplemental O ₂

Note. Mechanism of injury (MOI), heart rate (HR), blood pressure (BP), oxygen saturation (SpO₂), respiration rate (RR), body temperature (temp), gunshot wound (GSW), milligram (mg), oxygen (O₂), milliliters (mL), right lower extremity (RLE), total body surface area (TBSA), left lower extremity (LLE), right upper extremity (RUE), traumatic brain injury (TBI)

Appendix C. Questionnaires

Pre-Test Questionnaire

The information requested on this questionnaire is for the purposes of understanding your background and military history. ***Only your Subject number will be used in further documentation.***

Do you have a current DD-2292 (cleared for flight or simulator duties)? YES / NO

If you answered **NO** to this question, **please stop here**, and return the questionnaire to personnel.

Are you **currently** taking any medications which induce drowsiness? YES / NO
Example: Over-the-counter antihistamines.

Have you consumed any alcohol or sedatives within the past 24 hours following the regulation for exogenous factors (AR 40-8)? YES / NO

If you answered **YES** to either question above, **please stop here**, and return the questionnaire to personnel.

Age: _____ Biological Sex: _____ Male _____ Female

Ethnicity (if you prefer not to disclose, leave blank):

_____ African American (non-Hispanic) _____ Asian/Pacific Islander
_____ Caucasian (non-Hispanic) _____ Latino or Hispanic
_____ Native American _____ Other: _____

Service Component: _____ Active Duty _____ National Guard _____ Reserves

Current MOS: _____

Rank: _____ **Years at this Rank:** _____

Time in military aviation career: _____ Number of Deployments: _____

Combined Total Length of Deployments: _____

Please list the type(s) of aircraft you have flown **during your current military career** and the approximate hours in each type:

Type	Hours	Years Flown	PC Qualified?	Hours as PC
			YES / NO	
			YES / NO	
			YES / NO	
			YES / NO	

What is the approximate number of hours you have flown during MEDEVAC missions?

This space is intentionally blank.

Post-Test Questionnaire

Please rank the following on a scale of 1 to 5.

How helpful did you find the STEPS?				
①	②	③	④	⑤
Not helpful at all		Moderately helpful		Very helpful
How helpful did you find the Medic's guidance?				
①	②	③	④	⑤
Not helpful at all		Moderately helpful		Very helpful
How trustworthy were the STEPS recommendations?				
①	②	③	④	⑤
Not trustworthy at all		Moderately trustworthy		Very trustworthy
How trustworthy were the Medic's recommendations?				
①	②	③	④	⑤
Not trustworthy at all		Moderately trustworthy		Very trustworthy

Did you prefer the guidance from the STEPS or the Medic? Why?

Do you think that the STEPS would be an important addition to the cockpit? Why or why not?

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