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Overcoming Communication Barriers: An evaluation of communication devices for healthcare providers wearing powered air-purifying respirators (PAPRs)

Trevor Hebenstreit a, Geoffrey Ho b, Amy Tronnier a, Everett Chu b, Ivy Benjenk b, Paul Dangerfield b, Ryan Keneally b, Timothy Liu b, Marian Sherman b,∗

a The George Washington University School of Medicine and Health Sciences, Washington, DC, 20037, United States
b The George Washington University, Department of Anesthesiology & Critical Care Medicine, Washington, DC, 20037, United States

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ABSTRACT
Introduction: The COVID-19 pandemic has resulted in an increased use of Powered Air Purifying Respirators (PAPRs), by health care providers to mitigate the risk of viral transmission, especially for aerosol-generating procedures. In this study, we evaluate communication devices that could be used concurrently with PAPRs to promote improved communication.

Methods: We tested two devices, a Bluetooth earpiece and a throat microphone that operated over mobile networks, against a control scenario in a simulated operating room environment with participants donning PAPRs. Participants read a short paragraph to each other, transcribed short phrases, and evaluated the scenarios according to speech intelligibility, ease of use, and comfort.

Results: There were 30 participants of varying PAPR experience. The Bluetooth headset had the most accurate transcriptions, followed by control, and lastly the neckpiece (94.7% vs 88.4% vs 76%, p<0.001).

Conclusion: Communication devices have the potential to bridge but also worsen communications barriers between providers donning PAPRs.

1. Introduction
Healthcare systems worldwide have experienced a rapid and overwhelming need for high quantity and quality airborne precaution personal protective equipment (PPE) to mitigate the risk of COVID-19 transmission to healthcare providers (HCPs). For HCPs working directly with known COVID-19 infected patients or with patients whose COVID-19 status is undetermined, the Centers for Disease Control (CDC) and Occupational Safety and Health Administration (OSHA) recommend the use of N95 respirators. Select HCPs may not be protected adequately by an N95 mask due to a poor seal between the respirator’s face piece and the wearer’s face. In these circumstances, the use of a Powered Air-Purifying Respirators (PAPR) is recommended. A PAPR includes two primary pieces, a hood-like head covering and an air circulator. Theoretically it protects all wearers, regardless of facial anatomy or presence of facial hair. Additionally, when the clinical care of patients infected with the COVID-19 virus requires aerosol-generating intervention, it is recommended that HCPs wear PAPRs because aerosolizing procedures have been shown to confer a markedly increased risk of transmission to providers.

A PAPRs combination of a head-covering shroud and noise generating battery-powered air purifier impedes communication amongst members of the healthcare team as well as the patient. This impediment can inhibit both provider and patient safety. PAPRs have been found to substantially reduce speech intelligibility, word discrimination, and hearing clarity. HCPs have been found to have a 60% lower odds of correctly understanding a word spoken by a co-worker while wearing a PAPR. Miscommunications are a leading cause of serious medical errors. The use of PAPRs can clearly impair high quality team communication.

Within our institution PAPRs have become regularly utilized in the Emergency Department, Operating Rooms (ORs), Intensive Care Units, and throughout the hospital when providers care for patients with COVID-19 during times with significant potential for aerosol generation.

∗ Corresponding author at: George Washington School of Medicine and Health Sciences, Department of Anesthesiology and Critical Care Medicine, 2300 M St NW, 7th Floor, Suite 737, Washington, DC 20037, United States.
E-mail address: msherman@mfa.gwu.edu (M. Sherman).

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Though PAPRs offer several advantages, the difficulties they create with respect to communication are not negligible. The objective of this study was to test commercially available communication devices in order to evaluate possible methods to improve the quality of communication for HCPs donning PAPRs. The null hypothesis is that no device will significantly improve communication for providers wearing PAPRs.

2. Materials and methods

We initiated a prospective, controlled study of communication devices used in conjunction with PAPRs after receiving approval from the George Washington University School of Medicine and Health Sciences Institutional Review Board. Informed consent was not required because the study was less than minimal risk, and no protected health information (PHI) was collected. When the PAPR-related communication challenge was identified at the beginning of the COVID-19 pandemic, several solutions were proposed by various physicians, resulting in the selection and purchase of two communication devices. Chosen for their low cost and ostensible ease of use, two devices were investigated, a Bluetooth headset (Ejeas Technology Co Ltd, Shenzhen, China) and a Fanverim throat microphone (Shezhen Pengsheng E-Commerce Co Ltd, Shenzhen, China).

Healthcare providers from the perioperative and critical care related departments were invited via email to participate in the study. Participants were assessed in pairs. They each received education on how to use the various communication devices under evaluation, as well as an opportunity to trial the devices prior to assessment. Following the introduction, participants donned loose-fitting shroud PAPR hoods connected to battery-powered air filters. A simulated OR environment was set up with two chairs set seven feet apart (to approximate the length of a standard hospital bed), and a speaker playing simulated OR noise, including the sounds of a heart rate monitor, operating room announcements, and background clinical conversations. The simulated OR noise was calibrated to deliver approximately 50db of noise (Fig. 1).

Participants were each given a standardized communication script developed by authors RK, MS and EC, which were approximately equivalent in length and technical complexity. The script consisted of a paragraph to read, followed by 15 short phrases consisting of a combination of numbers and medical terminology (see Appendix). One participant, the designated listener, would listen to the spoken paragraph to subjectively evaluate overall speech intelligibility. The listener would then transcribe the dictated list of short phrases onto an answer sheet. Up to three repetitions could be requested for each phrase, which were noted by a facilitator. The listener then became the speaker and the same experiment was repeated with different standardized reading material of similar length and complexity. This was repeated for three scenarios: one with the Bluetooth headset, one with the throat microphone, and one with no communication device (control). Objective assessment of communication was measured by the number of phrases transcribed correctly out of 15, and the number of repetitions requested.

The participants were asked to rate the clarity of information received, the ease of sending information, and the comfort of wearing the device on a five point Likert scale at the end of every scenario. Participants were also asked to rank the three scenarios relative to each other using the same subjective categories after conclusion of the scenario.

The number of items correctly transcribed, the number of repetitions requested, and the subjective ratings were all analyzed as continuous measures using a repeated measures analysis of variance (ANOVA) model. The overall ranking was analyzed as a binary measure; we compared the percentage of participants that ranked a given scenario as the “best” using the χ² test. Statistical analysis was performed with STATA-C 15 (StataCorp, College Station, TX), and P values of <0.05 were considered significant.

This study was conducted in accordance with the SQUIRE guidelines for quality improvement studies.

3. Results

Thirty participants were enrolled in the study, and all completed the protocol without dropout. Participants were evenly distributed demographically and had a diversity of experience with PAPRs (Table 1). Participants most accurately transcribed phrases when receiving communication via the Bluetooth headset, followed by the control (no communication device), and lastly the throat microphone (94.7%vs 88.4%vs 76%; P<0.001). Participants also requested the least number of repetitions with the Bluetooth headset (P<0.001) (Fig. 2).

Participants ranked the Bluetooth headset first, followed by the control, and lastly the throat microphone (P<0.001) for ease of receiving information, ease of sending information, and comfort when scoring them on a five point Likert scale (Fig. 3). The majority of

![Fig. 1. Schematic of simulation set up.](image)

*7 feet approximates the length of standard hospital bed.
participants ordinarily ranked the Bluetooth headset as the best for receiving and sending information (Fig. 4). An equal number ordinarily ranked the Bluetooth headset and control (no device) best with regard to comfort ($P < 0.001$).

4. Discussion

To echo Bandaru et al., efficient and effective communication are paramount to the delivery of quality healthcare. This challenge has been markedly exacerbated by the need for extensive PPE due to the COVID-19 pandemic. We determined the Bluetooth headset can significantly improve the accurate transmission of information among HCPs wearing PAPRs compared to no device. Some communication devices may paradoxically create a further impediment to effective communication, as shown by the worse objective and subjective scores of the throat microphone compared to no device at all.

Currently there is no available PAPR developed with a built-in communication device; thus it is worth considering the characteristics that produce an ideal communication device for PAPR use in common clinical scenarios. The unique challenges posed by using any device in conjunction with a PAPR became evident when initially selecting devices to trial. First, noise-cancelling devices were excluded as they could
also cancel ambient noise and therefore reduce situational awareness. Secondly, half-duplex systems, or systems which required a push-to-talk system to operate (e.g. walkie-talkies), were too cumbersome and impractical. Even a touch-to-talk button that could be clipped to a participant’s scrubs beneath a protective-barrier gown had the tendency to shift in position making it impossible to locate and activate. Further, the voice-activation commands required by the half duplex devices to initiate transmission added an unacceptable delay to communication. Thirdly, it was critical that the device be comfortable to wear. Providers need to be able to wear the device with a PAPR for a significant time period such as a several hour operation or an entire shift in the ED or ICU. Fourth, the device should ideally have multiple-channels to allow for communication within a larger team. In addition, this channel should not be based over a mobile phone due to potential interference with cellular service. Finally, the device should be simple to clean and affordable.

The Bluetooth headset met most of these criteria. It was originally designed to be worn by helmeted motorcyclists and used for clear communication during road travel for extended periods of time. This may be why the headset was suitable for use under PAPRs. The limitation of this Bluetooth system is that it is restricted to two-way communication. A two-way device may not be adequate to overcome communication barriers since most clinical procedures and interventions require effective communication and coordination between larger, often multidisciplinary teams. Conversely, the throat microphone was poorly received overall despite also meeting most of the stated criteria. The poor performance of this device was presumed to be due to the need for precise placement over the larynx, and variability in the user’s neck anatomy led to variability in the device’s performance. The location of the device plays an important role in accurate voice transmission as well as the perception of comfort for this device. This device also requires an active cellular phone call between participants. Fluctuating cellular service within the hospital may have contributed to the poor outcomes. Further, there was concern that accessing cell phones while in PPE could lead to self-contamination.

Airway management is a critical procedure that requires clear, concise, and closed-loop communication between all providers. The environments in which intubations occur are often loud and can result in impaired speech intelligibility. The challenge exists even in the absence of using PAPRs, N-95 s, or other PPE. Studies have shown that at baseline the mean 24 hour noise level in ICUs is 54 ± 2.4 dB while the average noise level in Johns Hopkins ORs ranged from 62 to –66 dB with peaks of >120 dB. Even apart from the COVID-19 pandemic, multiple studies have shown that current hospital environments frequently exceed noise levels deemed conducive to patient and provider safety and that healthcare providers who frequently work in loud environments are susceptible to hearing loss, particularly anesthesiologists. Any additional barrier to effective communication or additional ambient noise (such as a PAPR) has the potential to exacerbate these safety risks. PAPRs, with or without the use of an N95, are an additional physical barrier that hinders communication and has proven to be an added challenge for providers. Hines et al. demonstrated that when given a choice between using a standard N95-FFR or a PAPR, most users would still elect to use a PAPR under scenarios of heightened risk despite perceptions of somewhat lower comfort and decreased communication abilities with PAPRs compared to N-95 respirators.

There are limitations of our study that would benefit from further research. There is no current gold standard for a communication device...
in this scenario, and therefore we had to rely on experts to select from a field of commercially available communication devices that were not expressly manufactured for this purpose. Further studies should also control for subjects’ level of prior experience using a PAPR. Although not measured objectively in this study, it was observed that while conducting this experiment, participants with more experience with PAPRs inherently spoke louder and enunciated their words more clearly than participants with limited PAPR experience. Additionally, future studies could obtain a baseline audiology screen of each of the participants to account and control for the differences in hearing ability prior to testing the devices.

5. Conclusion

Select communication devices can help bridge communication barriers introduced by wearing a PAPR in the clinical environment. Further research and development is necessary to improve communication between healthcare providers wearing PAPRs. Such communication aids will enhance both provider and patient safety. Additionally, teams of clinicians must have reliable equipment to communicate effectively and deliver safe care to patients in clinical circumstances that require coordinated team effort such as in an operating room or in an emergency room trauma bay. Lastly, it is clear that the results of this investigation can be applied to clinical scenarios beyond caring for patients with COVID-19 illness. Enhanced PPE and PAPRs are used to protect clinicians in the context of other communicable infectious diseases such as Ebola.

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Declaration of Competing Interest

None

Device A1

Paragraph
The patient is a 34 year old male who suffered a gunshot wound to the right flank. Leg is tourniquetted and bleeding is slowed. Portable alcohol breathalyzer was used in the field but device failed; nevertheless, the smell of alcohol is evident and the patient was found to have both cocaine and MDMA on his person. Patient refuses to speak to paramedics, but he is noted to be wearing a diabetic medical alert bracelet. Last BP 164/76, tachy at 118, respirations 24 and O2 sat is 98%.

List

| Device A1
| 10  23 Epinephrine |
| 93  76 Ephedrine |
| 48  19 Neosynephrine |
| 30  84 Vasopressin |
| 57  26 Tachycardia |
| 59  40 Bradycardia |
| 38  72 Pulseless |
| 16  71 Propofol |
| 28  93 Ketamine |
| 40  56 Etomidate |
| One milligram epinephrine |
| Cardiovert at 50 joules |
| Is it PEA? |
| GSW to the abdomen |
| Call the ICU |

Device A2

Paragraph
How’s it going on that side? I am concerned about the patient’s volume status. The EBL has been approximately 700 cc and urine output is down to a trickle. I’m noticing respiratory variation on my art line and the pressure is a bit soft but still responding to intermittent boluses of phenylephrine. What does the field look like? I’ll run an iSTAT, and call the blood bank to send up our 2 units PRBC. Probably a good idea to cross for another two units, maybe some platelets and FFP.

List

| Device A2
| 51  60 Etomidate |
| 49  28 Epinephrine |
| 36  41 Tachycardia |
| 75  62 Pulseless |
| 30  98 Ketamine |
| 23  14 Bradycardia |
| 90  57 Propofol |
| 68  30 Ephedrine |
| 18  29 Vasopressin |
| 46  57 Neosynephrine |

(continued on next page)
Device B1

Paragraph
A 33 year old man was brought to the emergency department after being found unresponsive at home. The patient’s roommate says last night, they went to a party and drank homemade liquor. Temp is 37 C, pulse is 128/min, respirations are 31 and shallow, and blood pressure is 87/52. Pulse ox on room air shows an O2 sat of 95%. The patient is unresponsive to painful stimuli. Pupils are 3 mm, equal, round and reactive to light and lungs are clear to auscultation.

List

| 40 | 56 | Etomidate |
| 28 | 93 | Ketamine  |
| 16 | 71 | Propofol  |
| 38 | 72 | Pulseless |
| 59 | 40 | Bradycardia |
| 57 | 26 | Tachycardia |
| 93 | 76 | Ephedrine |
| 48 | 19 | Neosynephrine |
| 30 | 84 | Vasopressin |

Defibrilate at 200 joules
Found down on F street
7.19, 60, 72 on 100%
Who is running this?
It's Afib
Multiple contusions

Device B2

Paragraph
A 27 year old female came to the hospital for evaluation of nausea and vomiting for the last two weeks. During the period she has also had increased urinary frequency and fatigue. She reports three episodes of non-bloody emesis. There is no personal or family history of serious illness. Her last menstrual period was 7 weeks ago. Physical exam shows bilateral breast tenderness. The remainder of the exam showed no abnormalities. After further evaluation, pregnancy test came back positive.

List

| 46 | 57 | Neosynephrine |
| 18 | 29 | Vasopressin  |
| 68 | 30 | Ephedrine   |
| 90 | 57 | Propofol    |
| 23 | 14 | Bradycardia |
| 30 | 98 | Ketamine    |
| 49 | 28 | Epinephrine |
| 36 | 41 | Tachycardia |
| 75 | 62 | Pulseless   |

Call cardiology stat
Press the sync button
Sats are falling
I think we need to intubate
Has anyone called the family?
Give a second dose of epi

Device C1

Paragraph
A 23 year old man comes to the emergency department because of shortness of breath and a productive cough for 3 days. He sustained trauma to the left hemithorax during a fight 3 weeks ago but didn’t seek medical care. Temperature is 38.3C, pulse is 94/min, Respirations are 17/min and BP is 118/78. Pulmonary exam shows decreased breath sounds over the right lower lung fields. CT scan of the chest shows fractures of the left 5th and 6th ribs and a dense fluid collection in the pleural space.
Device C2

Paragraph

A 20 year old female came to the office for evaluation of a dry cough and chest tightness for the past several weeks. The cough is worse at night and while playing field hockey. She frequently has a runny nose and nasal congestion. The patient has smoked one pack of cigarettes for the last 2 years, but she does not drink alcohol. Vital signs are all within normal limits. Pulse ox on room air shows 99%. I think the patient would benefit from Spirometry testing.

List

59 40 Bradycardia
57 26 Tachycardia
48 19 Neosynephrine
30 84 Vasopressin
93 76 Ephedrine
16 71 Propofol
38 72 Pulseless
28 93 Ketamine
40 56 Etomidate
42 year old multiple deep lacs
He received 12 of PRBCs
Did he get calcium yet?
He has a blown pupil
Her aine isn’t correlating
We need better access

List

23 14 Bradycardia
30 98 Ketamine
36 41 Tachycardia
75 62 Pulseless
49 28 Epinephrine
68 30 Ephedrine
90 57 Propofol
18 29 Vasopressin
46 57 Neosynephrine
Pulmonary contusion
INR is 2.2
Did she lose consciousness?
Neurosurg is on the way
No radial pulse
She went over the handlebars

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