RESEARCH REPORT

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Otoacoustic Emissions Testing to Identify Hearing Loss in the ICU: A Feasibility Study

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OBJECTIVES: Hearing impairment is associated with delirium among ICU patients and a lack of functional recovery among older ICU survivors. We assessed the feasibility of using otoacoustic emissions (OAEs) testing to screen for preexisting hearing loss in the ICU.

DESIGN: Pilot study.

SETTING: Medical ICU at a tertiary medical center.

PATIENTS: All adults (age ≥ 18) and admitted to the medical ICU between November 29, 2021, and December 03, 2021, were eligible for the study.

INTERVENTIONS: OAE is a noninvasive, nonparticipatory tool that is used to screen for hearing loss by detecting intracochlear motion in response to auditory stimulation. The presence or absence of OAE was tested at six frequencies (1 k, 1.5 k, 2 k, 3 k, 4 k hertz).

MEASUREMENTS AND MAIN RESULTS: The primary outcome of feasibility was defined a priori as completion of greater than or equal to 70% of attempted tests. Average time of test completion and barriers or facilitators were also measured as outcomes. A patient passed OAE testing if at least two of six frequencies were detected in at least one ear, suggesting they did not have moderate or severe hearing impairment (that would require an amplifier). Data were also gathered on demographics, delirium, ventilation, sedation, illness severity, and ambient noise. Of 31 patients approached, 23 (74.2%) underwent testing. Eight patients (25.8%) were unable to be tested, most commonly due to elevated ambient noise. Among the 18 patients with complete data, six patients screened positive for hearing loss. The average time for OAE test completion per ear was 152.6 seconds (SD = 97.6 s).

CONCLUSIONS: OAE testing is a feasible method to screen for hearing loss in the ICU, including in nonparticipatory patients. Identification of hearing loss would facilitate improved communication through interventions such as amplifiers and accommodations. Future studies should evaluate whether identification and treatment of hearing loss in the ICU may reduce delirium and improve post-ICU recovery.

KEYWORDS: delirium; hearing loss; intensive care unit; recovery

Nearly one third of adults 65 years old and older suffer from hearing loss (1). Adults with hearing loss incur increased medical costs, longer lengths of stay, and have a higher risk of readmission (2). In the ICU, preexisting hearing loss is associated with poorer functional recovery among older ICU survivors (3). Importantly, hearing loss is modifiable, and methods exist to address it in this population (4).

Currently, there are few, if any, processes in place to screen for hearing loss among hospitalized older adults. Furthermore, the ability to screen for hearing loss in the ICU is limited by the lack of a validated method to perform auditory assessments on patients who may be nonparticipatory. Otoacoustic

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KEY POINTS

Question: Is it feasible to use otoacoustic emissions (OAEs) testing, a method widely used in clinical practice to screen for hearing loss in newborns, to identify adult ICU patients with hearing loss (an important risk factor for delirium)?

Findings: In this pilot study of adults admitted to an ICU, OAE testing was a feasible method to identify hearing loss, including among nonparticipatory patients. Approximately ¾ of patients successfully completed testing with an average test time of approximately 5 minutes; of the ¼ who could not be tested, the most common barrier to testing was elevated ambient noise.

Meaning: To identify adult ICU patients with hearing loss (an important risk factor for ICU delirium and poor post-ICU functional recovery), it is feasible to use OAE testing, a brief method that may also be used in nonparticipatory patients.

emissions (OAEs) testing is a noninvasive, nonparticipatory tool that is used to screen newborns for hearing loss by detecting intracochlear motion in response to auditory stimulation (5). The absence of OAEs is consistent with significant hearing loss. As such, OAE testing is the primary instrument for early identification of hearing loss in the universal newborn screening (6). OAEs are used on adults in clinical settings (as part of a differential diagnosis test battery) but may have different sensitivities and specificities as the signals are less robust as we age (7). However, recent advances in technology have improved the ability to detect OAEs in adults (8).

In this pilot study, we aimed to assess the feasibility of hearing assessment in the ICU using OAE testing and identify barriers to OAE testing in the ICU.

METHODS

Participants and Setting

This feasibility study was conducted on a convenience sample of patients admitted to the adult medical ICU (MICU) at a large tertiary care center. All patients admitted to the MICU between November 29, 2021, and December 03, 2021, were approached. There were no exclusion criteria for the study. The institutional review board waived requirement of consent as a quality improvement project as the study procedures did not pose any risks greater than those presented by routine clinical care.

Procedures

Patients were approached to participate in the study if it did not interfere with medical or nursing care. Participants were introduced to the testing as a noninvasive hearing test that assessed the ear's response to external stimuli. To reduce ambient noise, the participant's room door was closed with a sign in place that read "hearing test in progress." Efforts were made to reduce the amount of environmental sounds such as turning off suctioning devices. The external ear canal was examined to ensure the probe would appropriately fill the ear canal. The probe was then placed in the patient's ear and OAE testing commenced. If participants screened positive for likely hearing loss, they were given a hospital-provided portable amplifier to use and keep. Additionally, a message was sent to the primary care provider through the electronic medical record (EMR) suggesting a formal audiology evaluation, and the primary medical care team was notified of the results.

The Otodynamics Otoport Advance device transient-evoked OAE assessment protocol was used to detect the presence or absence of OAE at six frequencies (1 k, 1.5 k, 2 k, 3 k, 4 k hertz) that encompass the range most important for understanding speech (9). The device is a clinical handheld instrument with an attached silicone probe that is inserted into the participant's ear to approximate a hermetic seal. For transient-evoked OAE, the probe delivers a click sound (stimulus) that peaks in volume between 80 and 85 dB to the patient's ear and records for 10–20 ms to detect the presence of an OAE, a byproduct of sound processing in the cochlea that is consistent with no greater than a mild hearing loss. The click sound is rapidly repeated to create an average response that is recorded as a signal-to-noise ratio (SNR) (10). A loose probe seal, excessive ambient noise, or excessive internal noise from the patient (e.g., movement) can prevent the completion of the test. Emission results (e.g., SNR) for each frequency or the inability to perform the test after at least two attempts were recorded in a Research Electronic

Data Capture (REDCap) database. Between uses, the hard surfaces of the OAE equipment were cleaned with disinfectant wipes. A new silicone probe was used for each participant.

Measures

Data were gathered on demographics, delirium status (Confusion Assessment Method for the ICU [CAM-ICU], administered by a physician [R.K.] who had received CAM-ICU training by an intensivist with expertise in delirium assessments [L.E.F.]) (11), primary language, illness severity (Sequential Organ Failure Assessment) (12), ventilation status, sedation at the time of testing, Richmond Agitation-Sedation Scale (RASS) (13), and ambient noise. Ambient sound levels over a 5-minute period were recorded using REED Instruments R8050 Dual Range Sound Level Meter. Ambient noise was recorded in decibels A (dBA), which is a measure of sound weighted for how sensitive the human ear is to different frequencies. Traditionally environmental sound over 55 dBA can interfere with OAE assessment (14); however, modern technology has advanced in preventing ambient sound interfering with the test (note: 60 dBA is consistent with conversational levels) (15). For OAE results, an SNR greater than 3 was used to indicate the presence of OAE (16). OAE measures were recorded per ear and documented as a pass if at least two of six frequencies were detected in at least one ear. A pass suggested that the patient had no greater than mild hearing loss.

Outcomes

The primary outcome of feasibility was defined a priori as completion of greater than or equal to 70% of attempted tests. Percentage of tests completed, average time of test completion (seconds), and barriers to testing (elevated ambient noise, difficulty with probe insertion, poor stimuli stability, patient refusal, and poor seal between probe/external canal) were measured as outcomes.

Data Analysis

All study data were collected from chart review from the EMR or directly assessed by study personnel and entered in REDCap. Descriptive statistics were calculated as means and SDs for continuous variables and as frequencies and percentages for categorical variables.

RESULTS

Among the 31 participants, the mean age was 64.6 years (SD = 14.1 yr) and 13 participants (42%) were female (**Table 1**). Fifteen participants (48.4%) were mechanically ventilated, 8 (25.8%) were receiving sedative infusions, and 19 (61.3%) screened positive for delirium. Approximately half were drowsy or unarousable (RASS, –5 to –1 [14–45%]). The average ambient noise in patient rooms was 50.7 dB (SD = 4.0 dB).

Of the 31 participants, 23 (74.2%) were able to complete testing while 8 (23.8%) could not complete testing. There were no significant differences in terms of participant characteristics between those who underwent testing and those who were unable to complete testing (Table 1). The ambient noise in the room for participants who completed testing was 50.1 dB (SD = 4.3 dB) compared with 52.4 dB (SD = 2.1 dB) among participants who did not complete testing.

Among the 23 participants who completed testing, 12 (52.1%) showed no evidence of hearing loss, 5 (21.7%) did not have all measurements to determine hearing status, and 6 (26.1%) showed evidence of clinically significant hearing loss.

The average time for test completion per ear was roughly 2 ½ minutes or 152.6 seconds (SD = 97.6 s). The most common barriers to test completion were elevated ambient noise and difficulty with probe insertion (**Tables 2** and **3**). Other barriers included poor stimulus stability, patient refusal, and a poor seal between the probe and external canal.

DISCUSSION

In this study, we found that screening for hearing loss in the ICU is feasible using OAE testing and that screening for hearing loss can be performed on both ears in less than 5 minutes, on average. Importantly, OAE testing was feasible regardless of the patient's ability to participate; many participants were intubated and/or receiving sedative drips. Barriers to OAE testing included high ambient noise levels and difficulty with probe insertion. As hearing loss is a well-known risk factor for ICU delirium and has also

TABLE 1.
Participant Characteristics, Overall, and by Ability to Test (*n* = 31)

Characteristics	All Participants (*n* = 31)	Able to Test (*n* = 23)	Unable to Test (*n* = 8)
Mean age, yr, mean ± SD	64.6 ± 14.1	64.7 ± 13.5	64.1 ± 16.6
Female sex, *n* (%)	13 (41.9)	11 (47.8)	2 (25.0)
Sedation during assessment, *n* (%)	8 (25.8)	5 (21.7)	3 (37.5)
Mechanically ventilated, *n* (%)	15 (48.4)	10 (43.5)	5 (62.5)
Race/ethnicity, *n* (%)			
Asian	2 (6.5)	2 (8.7)	0 (0.0)
Black	5 (16.1)	4 (17.4)	1 (12.5)
Hispanic or Latino	1 (3.2)	0 (0.0)	1 (12.5)
White	21 (67.7)	15 (65.2)	6 (75.0)
Unknown	2 (6.5)	2 (8.7)	0 (0.0)
Primary language English, *n* (%)	29 (93.6)	22 (95.7)	7 (87.5)
RASS score, *n* (%)			
−5 to −1	14 (45.2)	9 (39.1)	5 (62.5)
0	16 (51.6)	13 (56.5)	3 (37.5)
> 1	1 (3.2)	1 (4.4)	0 (0.0)
Confusion Assessment Method for the ICU delirium screen, *n* (%)			
Unable to assess (RASS −4 or −5)	5 (16.1)	3 (13.0)	2 (25.0)
Positive	19 (61.3)	16 (69.6)	3 (37.5)
Negative	7 (22.6)	4 (17.4)	3 (37.5)
Owns hearing aid, *n* (%)			
Yes	2 (6.5)	2 (8.7)	0 (0.0)
No	17 (54.8)	15 (65.2)	2 (25.0)
Unable to answer	12 (38.7)	6 (26.1)	6 (75.0)
Mean ambient noise (decibels), mean ± SD	50.7 ± 4.0	50.1 ± 4.3	52.4 ± 2.1

RASS = Richmond Agitation-Sedation Scale.

TABLE 2.
Barriers Identified for Otoacoustic Emissions Testing per Ear, by the Overall Cohort and Among Participants Who Could Not Be Tested

Barriers to Testing	Overall Cohort (*n* = 62 Ears Among 31 Participants), *n* (%)	Participants Who Could Not Be Tested (*n* = 16 Ears Among Eight Participants), *n* (%)
Elevated ambient noise	10 (41.7)	8 (50.0)
Difficulty with probe insertion	9 (37.5)	5 (31.3)
Poor stimulus stability	2 (8.3)	2 (12.5)
Patient refusal	2 (8.3)	2 (12.5)
Poor seal between probe/external canal	1 (4.2)	0 (0.0)

TABLE 3.
Barriers to Otoacoustic Emissions Testing Among the Eight Participants Who Could Not Be Tested

Participant	Barriers to Testing[a]				
	Elevated Ambient Noise	Difficulty With Probe Insertion	Poor Stimulus Stability	Patient Refusal	Poor Seal Between Probe and External Canal
1				X[b]	
2	X				
3			X		
4	X	X			
5	X	x (left)			
6	X				
7	x (left)	X			
8	X				

[a]X indicates that the barrier was present in both ears, whereas x (laterality) indicates that that the barrier was present in one ear.
[b]Patient reported new chest and abdominal pain so the attempt was aborted and the medical team notified.

been associated with poor post-ICU outcomes, the use of OAE testing to screen for hearing loss among ICU patients may improve outcomes by facilitating the early recognition and treatment of hearing impairment.

Among older ICU patients, uncorrected sensory impairment may lead to increased delirium, and delirium adversely affects hospital outcomes and subsequent recovery (3, 17). Across all levels of care, hearing loss has been associated with an increased risk of hospital readmissions, longer lengths of stay, and decreased satisfaction with healthcare delivery (2, 18). Detecting hearing loss among critically ill patients can allow for interventions to improve communication, such as the use of amplifiers, reduction of background noise, or use of whiteboards or tablets (19).

Before this study, little was known about the feasibility of OAE testing in the ICU. One prior study, more than 2 decades ago, used OAE testing to screen for hearing loss in the surgical ICU and found that barriers to testing included early discharge, patient refusal, and patient agitation (20). The main strength of our study is its practical study design, particularly use of a screening method (OAE) that can be administered irrespective of sedation status or language barriers and that is already widely available in clinical practice. Our study is limited by the paucity of information on discrete OAE cut points for hearing loss in the adult population.

Elevated ambient noise and difficulty with probe insertion were the two most common barriers to OAE insertion in our study. No single cause of elevated ambient noise was identified in most cases; more commonly, cumulative background noise in the ICU environment increased ambient noise by small amounts (on average, 2 decibels) that were enough to be a barrier to OAE testing. However, changes could sometimes be made to reduce ambient noise in the test environment. For example, the mechanical ventilator increased ambient noise, but rolling the ventilator farther from the patient facilitated OAE testing. Cerumen was the major reason for probe insertion difficulties, which we were able to overcome at times by replacing the probe tip when it was occluded with wax. We did not have permission to clean the patient's ears as part of our study protocol. However, cerumen removal is relatively easy to perform and within the scope of nearly all ICU professionals, so basic cerumen removal can and should be included in future research and clinical protocols.

In conclusion, OAE testing is a feasible method for hearing loss screening in the ICU. Identification of hearing loss among ICU patients may lead to improved communication through interventions such as amplifiers, audiology referral, and accommodations. Future studies should evaluate whether the early identification of hearing loss through OAE testing facilitates early recognition and treatment of

hearing loss, potentially improving ICU and post-ICU outcomes.

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