JAMA Otolaryngology–Head & Neck Surgery | Original Investigation

Association of Cognitive Impairment Screening Scores With Improvements in Speech Recognition and Quality of Life After Cochlear Implantation

Mallory J. Raymond, MD; Cheng Ma, BS; Kara C. Schvartz-Leyzac, AuD, PhD, CCC-A; Elizabeth L. Camposeo, AuD, CCC-A; Shaun A. Nguyen, MD; Ted A. Meyer, MD, PhD; Theodore R. McRackan, MD, MSCR

Supplemental content

IMPORTANCE Many cochlear implant centers screen patients for cognitive impairment as part of the evaluation process, but the utility of these scores in predicting cochlear implant outcomes is unknown.

OBJECTIVE To determine whether there is an association between cognitive impairment screening scores and cochlear implant outcomes.

DESIGN, SETTING, AND PARTICIPANTS Retrospective case series of adult cochlear implant recipients who underwent preoperative cognitive impairment screening with the Montreal Cognitive Assessment (MoCA) from 2018 to 2020 with 1-year follow-up at a single tertiary cochlear implant center. Data analysis was performed on data from January 2018 through December 2021.

EXPOSURES Cochlear implantation.

MAIN OUTCOMES AND MEASURES Preoperative MoCA scores and mean (SD) improvement (aided preoperative to 12-month postoperative) in Consonant-Nucleus-Consonant phonemes (CNCp) and words (CNCw), AzBio sentences in quiet (AzBio Quiet), and Cochlear Implant Quality of Life-35 (CIQOL-35) Profile domain and global scores.

RESULTS A total of 52 patients were included, 27 (52%) of whom were male and 46 (88%) were White; mean (SD) age at implantation was 68.2 (13.3) years. Twenty-three (44%) had MoCA scores suggesting mild and 1 (2%) had scores suggesting moderate cognitive impairment. None had been previously diagnosed with cognitive impairment. There were small to medium effects of the association between 12-month postoperative improvement in speech recognition measures and screening positive or not for cognitive impairment (CNCw mean [SD]: 48.4 [21.9] vs 38.5 [26.6] [d = −0.43 (95% CI, −1.02 to 0.16)]; AzBio Quiet mean [SD]: 47.5 [34.3] vs 44.7 [33.1] [d = −0.08 (95% CI, −0.64 to 0.47)]). Similarly, small to large effects of the associations between 12-month postoperative change in CIQOL-35 scores and screening positive or not for cognitive impairment were found (global: d = 0.32 [95% CI, −0.59 to 1.23]; communication: d = 0.62 [95% CI, −0.31 to 1.54]; emotional: d = 0.26 [95% CI, −0.66 to 1.16]; entertainment: d = −0.005 [95% CI, −0.91 to 0.9]; environmental: d = −0.92 [95% CI, −1.86 to 0.46]; listening effort: d = −0.79 [95% CI, −1.65 to 0.22]; social: d = −0.51 [95% CI, −1.43 to 0.42]).

CONCLUSIONS AND RELEVANCE In this case series, screening scores were not associated with the degree of improvement of speech recognition or patient-reported outcome measures after cochlear implantation. Given the prevalence of screening positive for cognitive impairment before cochlear implantation, preoperative screening can be useful for early identification of potential cognitive decline. These findings support that screening scores may have a limited role in preoperative counseling of outcomes and should not be used to limit candidacy.

JAMA Otolaryngol Head Neck Surg. doi:10.1001/jamaoto.2022.4825
Published online February 2, 2023.

Author Affiliations: Department of Otolaryngology–Head and Neck Surgery, Medical University of South Carolina, Charleston.

Corresponding Author: Theodore R. McRackan, MD, MSCR, Department of Otolaryngology–Head and Neck Surgery, Medical University of South Carolina, 135 Rutledge Ave, 11th Floor, Charleston, SC 29425 (mcrackan@musc.edu).

In the US, hearing loss affects approximately 23% of adults and two-thirds of those aged 70 years and older.[1] In the past 2 decades, epidemiologic evidence has pointed toward an independent and linear association between age-related hearing loss and cognitive impairment.[2-8] In 2017, the Lancet Commission on dementia prevention, intervention, and care first identified hearing loss as a modifiable risk factor for the development of dementia.[9] Since then, increasing attention has been devoted to both identifying hearing-impaired patients at risk of dementia and exploring the potential of hearing rehabilitation to modify the risk of cognitive decline.

Representative of this trend is a growing number of cochlear implant centers that have begun to screen adults with hearing loss for cognitive impairment as part of the cochlear implant evaluation process. In a 2018 survey of cochlear implant audiologists, for example, 57% of respondents ranked cognition as moderately important to extremely important during the cochlear implant evaluation, and 41% considered cognitive decline a contraindication to implantation.[10] However, the utility of conducting cognitive screening tests for adults with hearing loss is unknown. First, the sensitivity and specificity of cognitive screening measures for detecting true cognitive decline in patients with severe-profound hearing loss have not been defined,[11] making it challenging for clinicians to understand the significance of a positive screening result in this population. Second, though there is a growing body of evidence demonstrating associations between several measures of cognitive function and cochlear implant speech recognition abilities,[12-17] only 1 study to date, to our knowledge, has investigated the association between preoperative cognitive screening test scores and postoperative improvement in speech recognition abilities.[18]

Given the limited data on the associations between cognitive impairment screening scores and postoperative cochlear implant speech recognition or patient-reported outcome measures (PROMs), it remains unknown how clinicians should be using cognitive screening scores to counsel patients regarding expected cochlear implant outcomes or if screening scores should be used to limit cochlear implant candidacy. Thus, the current study sought to determine whether there is an association between preoperative cognitive screening scores and improvements in postoperative cochlear implant speech recognition scores and PROMs in adult cochlear implant users.

Key Points

Question Is there an association between cognitive impairment screening scores and improvements in cochlear implant speech recognition and quality-of-life measures?

Findings In this case series of 52 adult cochlear implant recipients, nearly half of the patients screened positive for cognitive impairment. Preoperative Montreal Cognitive Assessment scores were not associated with change in preoperative to 12-month postoperative Consonant-Nucleus-Consonant phonemes and words, AzBio sentences in quiet, or Cochlear Implant Quality of Life-35 Profile scores.

Meaning Cognitive impairment screening scores may have a limited role in counseling patients regarding cochlear implant outcomes.

Methods

This article was drafted in accordance with the reporting guideline for case series.[19] The study was approved by the Medical University of South Carolina Institutional Review Board and was deemed exempt from needing patient consent.

Patient Selection

Data were retrospectively collected from a prospectively maintained database of patients undergoing cochlear implantation at a tertiary care center from January 2018 through December 2020. Participants included adult English-speaking patients (age ≥18 years) who met traditional standards for cochlear implantation according to Medicare and/or US Food and Drug Administration guidelines, were receiving their first-ear cochlear implant, and were screened for cognitive impairment using the Montreal Cognitive Assessment (MoCA). Demographic data included patient-reported race, among additional variables that have been directly or indirectly suggested to be associated with cochlear implant outcomes.[20] Cochlear implants were performed by 1 of 4 attending neurotologists (T.A.M., T.R.M.). All intraoperative device testing, postoperative programming, and speech recognition testing were performed by 3 cochlear implant audiologists (K.C.S.L., E.L.C.) at the same center.

Cognitive Impairment Screening

The standard MoCA is a clinician-administered tool used to screen for cognitive impairment.[21] The MoCA has a maximum score of 30 points and assesses 7 cognitive domains: visuospatial/executive function (5 points), naming (3 points), memory/delayed recall (5 points), attention (6 points), language (3 points), abstraction (2 points), and orientation (6 points). In a normal-hearing population, a score of 30 to 26 indicates normal cognition (NC), 25 to 18 indicates mild cognitive impairment (MCI), 17 to 10 indicates moderate cognitive impairment (MCI), and less than 10 indicates severe cognitive impairment.[22] For the purposes of this article, both mild and moderate cognitive impairment will be denoted as MCI. Note, given that the MoCA is a screening test, and diagnosis of cognitive impairment requires additional neuropsychiatric testing, no inferences are made in this article regarding the cognitive status of these patients. The MoCA was administered at the time of the cochlear implant evaluation by a trained audiologist in a quiet room, face-to-face, using both spoken and written instructions. Responses were recorded on the MoCA worksheet, and the total score and scores for each domain were calculated by the audiologist.

Quality-of-Life Evaluation

The Cochlear Implant Quality of Life-35 (CIQOL-35) Profile is a PROM that assesses the functional abilities of adult cochlear implant recipients within 6 domains: communication, assessing communication ability in different circumstances; emotional, assessing the impact of hearing on emotional well-being; entertainment, assessing the ability to enjoy television, radio, and music; environmental, assessing the ability to distinguish and localize environmental sounds; listening effort, assessing effort and fatigue associated with receptive communication; and social, assessing the ability to interact and enjoy interaction with groups.[23,24] An additional global score was calculated, providing a general assessment of cochlear implant-specific QOL. Scores were calculated for each domain and ranged from 0 (poorest QOL) to 100 (highest QOL). Patients completed the CIQOL-35 preoperatively and at the 12-month post-cochlear implant visit.

Audiological Testing

Preimplantation speech recognition was measured with hearing aids (personal or clinic owned) matched to National Acoustics Laboratory-revised linear (NAL-NL2) target gains.[25] Pre-cochlear implant and postimplant speech recognition testing was conducted using recorded materials presented from 0° azimuth at 60-dB sound pressure level. Ears were tested independently. Test materials included Consonant-Nucleus-Consonant (CNC) monosyllabic words (50-word list) and AzBio sentences in quiet and in noise.[26,27] Testing in noise was performed only for patients with AzBio Quiet scores of greater than 50% but this was performed for so few patients in the present study that it was not included in the analysis. Speech recognition testing was included for the implanted ear pre-cochlear implant and at 12 months postimplant.

Data Acquisition and Statistical Analysis

Retrospectively collected data included patient demographics, age at implantation, duration of hearing loss, use of hearing aid preoperatively, side of implantation, presence of comorbid mental illness or MCI, and MoCA scores. Duration of hearing loss before a cochlear implant was defined by self-reported number of years with hearing loss before implantation. Hearing aid use before a cochlear implant was defined as the patient's self-reported active implant-ear hearing aid use at the time of the cochlear implant evaluation (yes/no). Primary outcome measures were changes in CNC phonemes (CNCp), CNC words (CNCw), AzBio Quiet, and CIQOL-35 domains from pre-cochlear implant to 12 months postimplant.

Statistical analyses were performed using SPSS, version 27 (IBM Corporation). Categorical variables were summarized by frequency and percentage, and χ^2 tests were used to compare categorical preoperative variables between those with MCI and NC. Risk differences and 95% CIs are reported. Because only 1 patient screened positive for moderate cognitive impairment, there were insufficient data to compare outcomes between patients with mild and moderate cognitive impairment screening scores. Continuous variables were summarized by mean (SD). All continuous variables were tested for normal distribution with the Kolmogorov-Smirnov test, and all passed normality. Independent *t* tests were used to compare continuous preoperative variables and the mean improvement in speech and PROMs between those with MCI and those with NC. Cohen *d* effect sizes and 95% CIs (lower to upper) were calculated where appropriate.[28] Interpretation of effect sizes is listed in the eTable in Supplement 1. Established speech recognition test measurement errors were considered when reporting the clinical significance of score improvement after 12 months.[27,29]

Bivariate correlation was performed to determine, primarily, whether preoperative MoCA scores, and secondarily, any other continuous variable, correlated with improvements of postoperative speech recognition outcomes. The independent variables examined were MoCA scores, age at implantation, and duration of hearing loss. Pearson correlation coefficients (*r*) and 95% CIs are reported. Additionally, independent *t* tests were used to assess differences in mean improvements of postoperative speech recognition outcomes for dichotomous variables (sex, psychiatric comorbidity, and preoperative hearing aid use). Cohen *d* effect sizes and 95% CIs (lower to upper) are reported.

Results

Screening Results

A total of 52 patients (27 [52%] men; mean [SD] age at implantation, 68.2 [13.3] years) were included in the study, and their characteristics are summarized in **Table 1**. The mean (SD) MoCA score for the cohort was 25.8 (2.9) (range: 16-30). Twenty-eight patients (54%) had scores suggesting NC, 23 (44%) had scores suggesting mild cognitive impairment, and 1 (2%) had scores suggesting moderate cognitive impairment. No patients had been previously diagnosed with cognitive impairment. Between those who screened positive for MCI and those with NC, there were no differences in the sex, race, age at implantation, duration of hearing loss, use of hearing aid preoperatively, presence of comorbid mental illness, or preoperative speech recognition scores (Table 1).

Association Between Speech Recognition Outcomes and Cognitive Impairment Screening Results

Of the 52 patients who underwent 12-month postoperative speech recognition testing, 6 did not have complete CNCp and CNCw testing, and 2 did not have complete AzBio Quiet testing. Combined, patients demonstrated clinically significant mean (SD) preimplant to 12-month postimplant improvements in CNCp (47.9 [24.4]), CNCw (42.8 [23.2]), and AzBio Quiet (46 [33.3]) scores. Small to medium effects were found in the differences in the mean (SD) preimplant to 12-month postimplant speech recognition improvements between patients who screened positive for MCI compared with those who did not (CNCp: 50.6 [24.8] vs 45.8 [24.5] [*d* = −0.19 (95% CI, −0.78 to 0.39)]; CNCw: 48.4 [21.9] vs 38.5 [26.6] [*d* = −0.43 (95% CI, −1.02 to 0.16)]; AzBio Quiet: 47.5 [34.3] vs 44.7 [33.1] [*d* = −0.08 (95% CI, −0.64 to 0.47)]) (**Table 2**); because of the width of the confidence intervals, no definitive conclusions can be made regarding the association. Similarly, for patients 65 years or older, small to medium effects were found in the differences in speech recognition improvements between those who screened positive for MCI and those who did not (Table 2).

Bivariate Analyses

On bivariate analyses, preoperative MoCA scores weakly correlated with speech recognition outcomes (CNCp [*r* = −0.17

Table 1. Patient Characteristics

Characteristic	Mean (SD) All patients (n = 52)	Mean (SD) Cognitive impairment (n = 24)	Cohen *d* or % risk difference (95% CI)
Sex, No. (%)			
Female	25 (48)	13 (54)	11% (−15% to 35%)
Male	27 (52)	11 (46)	
Race, No. (%)			
Black	6 (12)	3 (12)	4% (−38% to 47%)
White	46 (88)	21 (88)	
Preoperative hearing aid use, No. (%)			
Yes	44 (85)	19 (79)	19% (−56% to 17%)
No	8 (15)	5 (21)	
Age at implantation, y	68.2 (13.3)	67.5 (12.3)	0.09 (−0.54 to 0.64)
Duration of hearing loss, y	22.2 (14.1)	20.5 (14.2)	0.23 (−0.32 to 0.78)
Total MoCA score	25.8 (2.9)	23.4 (2.3)	2.27 (1.56 to 2.97)
Neuropsychiatric comorbidities, No. (%)			
Anxiety	11 (21)	5 (21)	1% (−23% to 22%)
Depression	8 (15)	5 (21)	10% (−10% to 29%)
Preoperative CNCp	27.7 (24.4)	27.8 (23.8)	−0.01 (−0.55 to 0.54)
Preoperative CNCw	14.7 (16.2)	13.5 (14.5)	0.14 (−0.41 to 0.68)
Preoperative AzBio Quiet	22.3 (25.2)	22.9 (26.0)	−0.05 (−0.59 to 0.49)

Abbreviations: AzBio Quiet, AzBio sentences in quiet; CNCp, Consonant-Nucleus-Consonant phonemes; CNCw, Consonant-Nucleus-Consonant words; MoCA, Montreal Cognitive Assessment.

Table 2. Comparison of Change in Pre–Cochlear Implant to 12-Month Postimplant Speech Recognition Outcomes Between Groups With MCI and NC

	Mean (SD) [No.]				Age ≥65 y, mean (SD) [No.]		
	All patients	NC	MCI	Cohen *d* (95% CI)	NC	MCI	Cohen *d* (95% CI)
CNCw	42.8 (23.2) [46]	38.5 (26.6) [26]	48.4 (21.9) [20]	−0.43 (−1.02 to 0.16)	34.6 (25.4) [18]	42.7 (23.4) [14]	−0.33 (−1.03 to 0.37)
CNCp	47.9 (24.4) [46]	45.8 (24.5) [26]	50.6 (24.8) [20]	−0.19 (−0.78 to 0.39)	43.9 (25.9) [18]	43.9 (24.7) [14]	0.001 (−0.68 to 0.70)
AzBio Quiet	46.0 (33.3) [50]	44.7 (33.1) [26]	47.5 (34.3) [24]	−0.08 (−0.64 to 0.47)	45.9 (37.9) [19]	38.9 (35.0) [17]	0.19 (−0.47 to 0.85)

Abbreviations: AzBio Quiet, AzBio sentences in quiet; CNCp, Consonant-Nucleus-Consonant phonemes; CNCw, Consonant-Nucleus-Consonant words; MCI, mild and moderate cognitive impairment combined; NC, normal cognition.

Table 3. Bivariate Analysis of Patient Factors and Mean Improvement in 12-Month Speech Recognition Scores

	r (95% CI) CNCp	CNCw	AzBio Quiet
MoCA	−0.17 (−0.44 to 0.13)	−0.17 (−0.44 to 0.12)	−0.07 (−0.34 to 0.21)
Age	−0.21 (−0.47 to 0.09)	−0.26 (−0.51 to 0.04)	−0.19 (−0.45 to 0.09)
Duration of HL	0.16 (−0.14 to 0.43)	0.07 (−0.22 to 0.36)	0.08 (−0.2 to 0.35)

Abbreviations: AzBio Quiet, AzBio sentences in quiet; CNCp, Consonant-Nucleus-Consonant phonemes; CNCw, Consonant-Nucleus-Consonant words; HL, hearing loss; MoCA, Montreal Cognitive Assessment.

(95% CI, −0.44 to 0.13)], CNCw [*r* = 0.17 (95% CI, −0.44 to 0.12)], and AzBio Quiet [*r* = 0.07 (95% CI, −0.34 to 0.21)]) (**Table 3**). Similarly, all other factors analyzed weakly correlated with speech recognition outcomes.

Association Between Dichotomous Patient Factors and Speech Recognition Outcomes

Small to medium effects were found in the differences in the mean preimplant to 12-month postimplant speech recognition improvements between men and women, those with and without psychiatric comorbidities, and those who reported preoperative hearing aid use and those who did not (*d* range: −0.12 to 0.44) (**Table 4**).

Association Between Change in CIQOL-35 Profile Domain and Global Scores and Cognitive Impairment Screening Results

Given the relatively recent validation of the CIQOL-35 Profile,[24] fewer patients had complete preimplant and postimplant scores (n = 21). The mean (SD) MoCA score for these patients was 26.8 (2.7) (range: 21-30); patients with NC (n = 14, 67%) had a mean (SD) score of 28.4 (1.6) compared with patients with MCI (n = 7, 33%) who had a mean (SD) score of 23.6 (1.6), *d* = 2.98 (95% CI, 1.66-4.27). Combined, patients demonstrated mean (SD) preimplant to 12-month postimplant improvement in the global (4.8 [23.2]), communication (8.0 [24.0]), emotional (15.7 [33.2]), entertainment (15.7 [29.2]),

Table 4. Difference in Mean Improvement in 12-Month Speech Recognition Scores for Dichotomous Patient Factors

	CNCp, mean (SD)	Difference in mean (Cohen *d*) [95% CI]	CNCw, mean (SD)	Difference in mean (Cohen *d*) [95% CI]	AzBio Quiet, mean (SD)	Difference in mean (Cohen *d*) [95% CI]
Sex						
Female	52.1 (19.3)	−8.48 (−0.35) [−0.93 to 0.24]	44.2 (22.5)	−2.78 (−0.12) [−0.69 to 0.46]	52.7 (28.5)	−12.40 (−0.37) [−0.93 to 0.19]
Male	43.6 (28.6)		41.4 (24.2)		40.3 (36.6)	
Preoperative hearing aid use						
Yes	46.3 (24.5)	10.74 (0.44) [−0.37 to 1.20]	41.2 (23.2)	8.85 (0.38) [−0.43 to 1.19]	44.2 (34.0)	11.46 (0.34) [−0.42 to 1.10]
No	57.0 (24.4)		50.3 (23.4)		55.6 (29.8)	
Psychiatric comorbidity						
Yes	40.8 (25.2)	9.06 (0.37) [−0.34 to 1.07]	36.0 (19.0)	8.67 (0.37) [−0.33 to 1.10]	73.4 (23.6)	9.21 (−0.14) [−0.81 to 0.54]
No	49.9 (24.3)		44.7 (24.1)		69.8 (27.7)	

Abbreviations: AzBio Quiet, AzBio sentences in quiet; CNCp, Consonant-Nucleus-Consonant phonemes; CNCw, Consonant-Nucleus-Consonant words.

Table 5. Comparison of Mean Change in CIQOL-35 Scores Between Groups With MCI and NC at the 12-Month Evaluation

	Mean (SD)			
Domain	All patients (n = 21)	NC (n = 14)	MCI (n = 7)	Cohen *d* (95% CI)
Global	4.8 (23.2)	7.4 (21.4)	−0.2 (27.4)	0.32 (−0.59 to 1.23)
Communication	8.0 (24.0)	12.8 (18.9)	−1.8 (31.3)	0.62 (−0.31 to 1.54)
Emotional	15.7 (33.2)	18.5 (29.7)	9.9 (41.4)	0.26 (−0.66 to 1.16)
Entertainment	15.7 (29.2)	15.6 (32.0)	15.8 (24.8)	−0.005 (−0.91 to 0.9)
Environmental	24.3 (17.2)	19.4 (17.1)	34.1 (13.4)	−0.92 (−1.86 to 0.46)
Listening effort	16.7 (19.8)	12.1 (21.4)	25.9 (13.1)	−0.79 (−1.65 to 0.22)
Social	13.4 (25.5)	9.0 (28.1)	22.0 (18.2)	−0.51 (−1.43 to 0.42)

Abbreviations: CIQOL-35, Cochlear Implant Quality of Life-35; MCI, mild and moderate cognitive impairment combined; NC, normal cognition.

environmental (24.3 [17.2]), listening effort (16.7 [19.8]), and social (13.4 [25.5]) domains. There were small to large effects in the differences in the mean (SD) domain score improvements between patients who screened positive for MCI compared with those who did not (global: −0.2 [27.4] vs 7.4 [21.4] [*d* = 0.32 (95% CI, −0.59 to 1.23)]; communication: −1.8 [31.3] vs 12.8 [18.9] [*d* = 0.62 (95% CI, −0.31 to 1.54)]; emotional: 9.9 [41.4] vs 18.5 [29.7] [*d* = 0.26 (95% CI, −0.66 to 1.16)]; entertainment: 15.8 [24.8] vs 15.6 [32.0] [*d* = −0.005 (95% CI, −0.91 to 0.9)]; environmental: 34.1 [13.4] vs 19.4 [17.1] [*d* = −0.92 (95% CI, −1.86 to 0.46)]; listening effort: 25.9 [13.1] vs 12.1 [21.4] [*d* = −0.79 (95% CI, −1.65 to 0.22)]; social: 22.0 [18.2] vs 9.0 [28.1] [*d* = −0.51 (95% CI, −1.43 to 0.42)]) (**Table 5**).

Discussion

The current study addresses an important problem facing cochlear implant clinicians: how the results of cognitive screening tests should be incorporated into preoperative discussions of postoperative expectations with potential cochlear implant users. Our results suggest that there is likely not an association between patient preimplant cognitive screening results in the normal and mild range and improvement in speech recognition or PROM scores. These are important findings for 2 main reasons. First, clinically administered preoperative cognitive screening tests, as opposed to other cognitive function tests, often represent the only measures of cognitive ability available to clinicians evaluating a potential cochlear implant user. Second, patients with preoperative cognitive screening scores that indicate concern for mild cognitive impairment may have similar cochlear implant outcomes as those with normal screening scores. These findings support those of Buchman et al,[18] who found no difference in improvements in speech recognition in quiet and noise between those who did and did not screen positive for MCI in a prospective nonrandomized trial of 96 cochlear implant recipients. Together these studies suggest that preoperative cognitive screening scores, particularly those in the mild range, should not alone limit cochlear implant candidacy nor be used alone to counsel patients on postoperative expectations.

Though preoperative cognitive ability has previously been found to be associated with postoperative speech recognition outcomes,[12-17] a distinction between the measures of cognitive ability between these and our study must be made. Many cognitive processes, such as those measured by Moberly et al, including inhibition-concentration,[12,15] information processing speed,[15] nonverbal reasoning,[13] and verbal learning and memory,[14] that have been found to correlate with cross-sectional cochlear implant speech recognition abilities are inherently different than those assessed in cognitive screening tests like the MoCA. They are more complex, often conducted in a laboratory setting for individuals without clinical cognitive impairment, can be challenging for cognitively intact adults, and often measure a single construct of cognitive function. In contrast, cognitive screening tests can be routinely administered in the clinical setting with the purpose of identifying patients at risk of clinically significant cognitive decline and who might require further diagnostic testing.[30] They are designed to be sensitive to cognitive decline but not specific to certain cognitive constructs or diagnoses.

In addition, even studies investigating the associations between specific cognitive function tests and cochlear implant outcomes have had mixed results. For example, early cochlear implant studies investigating the predictive power of IQ,[31] visual monitoring abilities,[32] and reading span performance[33] generally found absent to weak correlations with speech recognition outcomes. More recent studies examining the association between longitudinal speech recognition outcomes and preoperative cognition have also had mixed results. Some have identified associations between a few cognitive measures—working memory,[34,35] verbal learning,[36] verbal fluency,[37] and inhibitory control[38]—and postoperative improvement in speech recognition outcomes at various time points, but others have found little[39] to no[40] correlations between different measures of cognition and longitudinal outcomes. These discrepancies are not only explained by differences in cognitive test batteries, but also by differences in the timing of postoperative speech testing and components of speech testing batteries.

Patient-reported real-world functional abilities are being increasingly recognized as important postoperative measures of cochlear implant benefit, but the association between cognition and these outcomes has not been widely studied. In a cross-sectional study assessing a partial least regression squares model of predictors of cochlear implant outcomes, it was found that cognitive measures played a much larger role in predicting PROMs than speech recognition outcomes, though the model was able to explain only 53% of the PROM variance.[16] Additional associations found between cognition and postimplant PROMs include those between a visual measure of concentration and patient-reported social interactions[41] and tests of rapid reading and general intelligence with some subdomains of the Nijmegen Cochlear Implant Questionnaire.[42] To our knowledge, the present study is the first to assess the association between preoperative cognitive impairment screening scores and improvement in PROMs. The absence of clinically significant differences in PROM improvements between those with MCI and NC suggests that patients who screen positive for MCI may obtain similar improvements in self-reported functional abilities, which could influence preimplant patient counseling.

Despite the weak strength of association found between cognitive screening scores and postoperative speech recognition and PROMs in this study, cognitive screening during cochlear implant evaluations remains important. The prevalence of positive cognitive impairment screening in the study cohort was quite high at nearly 50%. Similarly high rates of cognitive screening failures were identified in the CI532 study group, during which 59% of all patients[18] and 64% of patients 65 years and older[43] screened positive for mild cognitive impairment. In 2018, it was estimated that the prevalence of mild cognitive impairment increased from 8.4% for adults aged 65 to 69 years to 25.2% for adults aged 80 to 84 years.[44] Given the known association between cognitive decline and age-related hearing loss, it is not surprising that the prevalence of cognitive impairment in this hearing-impaired cohort is higher than what would be expected for a similarly aged population. Importantly, no patient in this study had previously been diagnosed with cognitive impairment. This suggests that cognitive screening assessments included in cochlear implant evaluations have the potential for very early identification of patients who are at risk of further cognitive decline. Yet, survey findings have shown that a significant portion of cochlear implant clinicians who identify potential cognitive impairment from a screening test might not offer a referral for further diagnostic neuropsychiatric testing.[10,45] Though the reasons for this remain unknown, low rates of referral for diagnostic testing among these clinician groups suggest that missed opportunities to initiate potentially helpful further cognitive diagnostic evaluations might be widespread.[44]

Limitations

There are several limitations to this study. First, our analysis included only patients with preoperative MoCA scores. Some patients undergoing cochlear implant evaluations did not complete a MoCA because of time constraints, but exclusion of these patients could have biased MCI prevalence in either a positive or negative direction. Additionally, only 1 patient was found to have a MoCA score in the moderate range, making our results primarily applicable to patients with concern for mild cognitive impairment rather than generalizable to patients with more severe cognitive impairment. Second, given the relatively recent practice of performing preimplant cognitive assessments and newness of the CIQOL-35, there was a relatively small population studied. The small study size, which contributes to the wide confidence intervals, limits the ability to draw definitive conclusions. Larger samples will provide more precise estimates of the true effect and allow for more definitive conclusions to be drawn regarding the compatibility of the results with clinically meaningful effects. However, for outcomes in this study with medium to large effect sizes, consideration of testing measurement error influenced our interpretation of the results. For example, the mean (SD) difference in CNCw improvement between those who screened positive for MCI and those who did not (48.4 [21.9] vs 38.5 [26.6]) was approximately 10%. While this corresponded to a medium effect size, a 10% difference in CNCw is within the testing measurement error and would thus not be considered clinically significant. In the future, outcomes should be assessed in a larger sample, both before and after 1 postoperative year to account for differences in rates of improvement and be interpreted in the context of the test's measurement error. Furthermore, pooling of data across multiple similar studies, such as that done by Zhao et al,[20] would greatly improve the generalizability of the results. Third, and perhaps most importantly, the standard MoCA is not validated for use in the profoundly hearing-impaired population, and though 1 attempt at designing a more suitable test, termed the Hearing-Impaired MoCA (HI-MoCA), has been made,[46] there is no truly validated alternative cognitive screening tool for those with hearing impairment.[11] Thus, the false-positive rate remains unknown, and it is possible that patients who screened positive for MCI might have NC. This hypothesis further supports the recommendation against using screening scores alone to counsel patients on postimplant expectations. Lastly, though all patients who screened positive for MCI were counseled on scores and offered referral for further evaluation, we were unable to collect data on follow-up testing, which could be helpful in assessing the validity of the cognitive screening test in this population.

Conclusions

In this retrospective case series, preoperative cognitive screening scores were weakly associated with improvements in speech recognition or PROM scores after cochlear implantation, suggesting that cognitive screening scores alone should not be used to limit cochlear implant candidacy and might have a limited role in discussions of postoperative expectations. Given the relatively high prevalence of MCI identified by the MoCA in patients undergoing cochlear implant evaluations, cognitive screening can be used to help initiate comprehensive diagnostic cognitive evaluation, if desired by patients and families. Future investigation into associations between cognitive impairment screening and cochlear implant outcomes should seek to optimize the validity of screening tests and investigate improvements in long-term PROM and speech recognition scores for hearing-impaired adults with mild, moderate, and severe cognitive impairment.

ARTICLE INFORMATION

Accepted for Publication: December 2, 2022.

Published Online: February 2, 2023. doi:10.1001/jamaoto.2022.4825

Author Contributions: Dr Raymond had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.
Concept and design: All authors.
Acquisition, analysis, or interpretation of data: Raymond, Ma, Camposeo, Nguyen, Meyer, McRackan.
Drafting of the manuscript: Raymond, Ma, Camposeo, Nguyen, McRackan.
Critical revision of the manuscript for important intellectual content: All authors.
Statistical analysis: Raymond, Nguyen, McRackan.
Obtained funding: McRackan.
Administrative, technical, or material support: Raymond, Schvartz-Leyzac, Camposeo, McRackan.
Supervision: Schvartz-Leyzac, Nguyen, Meyer, McRackan.

Conflict of Interest Disclosures: Dr Schvartz-Leyzac reported receiving salary from Medical University of South Carolina and University of Michigan outside the submitted work. Dr McRackan reported receiving personal fees (advisory board member) from Envoy Medical outside the submitted work. No other disclosures were reported.

Disclaimer: Dr McRackan is on the Editorial Board of *JAMA Otolaryngology–Head & Neck Surgery* but was not involved in any of the decisions regarding review of the manuscript or its acceptance.

Meeting Presentation: This work was previously presented at the American Neurotology Society meeting during the annual Combined Otolaryngology Sections Meeting; April 27-May 1, 2022; Dallas, Texas.

Data Sharing Statement: See Supplement 2.

REFERENCES

1. Goman AM, Lin FR. Prevalence of hearing loss by severity in the United States. *Am J Public Health*. 2016;106(10):1820-1822. doi:10.2105/AJPH.2016.303299

2. Loughrey DG, Kelly ME, Kelley GA, Brennan S, Lawlor BA. Association of age-related hearing loss with cognitive function, cognitive impairment, and dementia: a systematic review and meta-analysis. *JAMA Otolaryngol Head Neck Surg*. 2018;144(2):115-126. doi:10.1001/jamaoto.2017.2513

3. Lim MYL, Loo JHY. Screening an elderly hearing impaired population for mild cognitive impairment using Mini-Mental State Examination (MMSE) and Montreal Cognitive Assessment (MoCA). *Int J Geriatr Psychiatry*. 2018;33(7):972-979. doi:10.1002/gps.4880

4. Gurgel RK, Ward PD, Schwartz S, Norton MC, Foster NL, Tschanz JT. Relationship of hearing loss and dementia: a prospective, population-based study. *Otol Neurotol*. 2014;35(5):775-781. doi:10.1097/MAO.0000000000000313

5. Lin FR, Yaffe K, Xia J, et al; Health ABC Study Group. Hearing loss and cognitive decline in older adults. *JAMA Intern Med*. 2013;173(4):293-299. doi:10.1001/jamainternmed.2013.1868

6. Huh M. The relationships between cognitive function and hearing loss among the elderly. *J Phys Ther Sci*. 2018;30(1):174-176. doi:10.1589/jpts.30.174

7. Harrison Bush AL, Lister JJ, Lin FR, Betz J, Edwards JD. Peripheral hearing and cognition: evidence from the Staying Keen in Later Life (SKILL) study. *Ear Hear*. 2015;36(4):395-407. doi:10.1097/AUD.0000000000000142

8. Lin FR, Ferrucci L, Metter EJ, An Y, Zonderman AB, Resnick SM. Hearing loss and cognition in the Baltimore Longitudinal Study of Aging. *Neuropsychology*. 2011;25(6):763-770. doi:10.1037/a0024238

9. Livingston G, Huntley J, Sommerlad A, et al. Dementia prevention, intervention, and care: 2020 report of the Lancet Commission. *Lancet*. 2020;396(10248):413-446. doi:10.1016/S0140-6736(20)30367-6

10. Prentiss S, Snapp H, Zwolan T. Audiology practices in the preoperative evaluation and management of adult cochlear implant candidates. *JAMA Otolaryngol Head Neck Surg*. 2020;146(2):136-142. doi:10.1001/jamaoto.2019.3760

11. Raymond M, Barrett D, Lee DJ, Peterson S, Raol N, Vivas EX. Cognitive screening of adults with postlingual hearing loss: a systematic review. *Otolaryngol Head Neck Surg*. 2021;164(1):49-56. doi:10.1177/0194599820933255

12. Moberly AC, Houston DM, Castellanos I. Non-auditory neurocognitive skills contribute to speech recognition in adults with cochlear implants. *Laryngoscope Investig Otolaryngol*. 2016;1(6):154-162. doi:10.1002/lio2.38

13. Mattingly JK, Castellanos I, Moberly AC. Nonverbal reasoning as a contributor to sentence recognition outcomes in adults with cochlear implants. *Otol Neurotol*. 2018;39(10):e956-e963. doi:10.1097/MAO.0000000000001998

14. Pisoni DB, Broadstock A, Wucinich T, et al. Verbal learning and memory after cochlear implantation in postlingually deaf adults: some new findings with the CVLT-II. *Ear Hear*. 2018;39(4):720-745. doi:10.1097/AUD.0000000000000530

15. Moberly AC, Reed J. Making sense of sentences: top-down processing of speech by adult cochlear implant users. *J Speech Lang Hear Res*. 2019;62(8):2895-2905. doi:10.1044/2019_JSLHR-H-18-0472

16. Skidmore JA, Vasil KJ, He S, Moberly AC. Explaining speech recognition and quality of life outcomes in adult cochlear implant users: complementary contributions of demographic, sensory, and cognitive factors. *Otol Neurotol*. 2020;41(7):e795-e803. doi:10.1097/MAO.0000000000002682

17. Tamati TN, Vasil KJ, Kronenberger WG, Pisoni DB, Moberly AC, Ray C. Word and nonword reading efficiency in postlingually deafened adult cochlear implant users. *Otol Neurotol*. 2021;42(3):e272-e278. doi:10.1097/MAO.0000000000002925

18. Buchman CA, Herzog JA, McJunkin JL, et al; CI532 Study Group. Assessment of speech understanding after cochlear implantation in adult hearing aid users: a nonrandomized controlled trial. *JAMA Otolaryngol Head Neck Surg*. 2020;146(10):916-924. doi:10.1001/jamaoto.2020.1584

19. Kempen JH. Appropriate use and reporting of uncontrolled case series in the medical literature. *Am J Ophthalmol*. 2011;151(1):7-10.e1. doi:10.1016/j.ajo.2010.08.047

20. Zhao EE, Dornhoffer JR, Loftus C, et al. Association of patient-related factors with adult cochlear implant speech recognition outcomes: a meta-analysis. *JAMA Otolaryngol Head Neck Surg*. 2020;146(7):613-620. doi:10.1001/jamaoto.2020.0662

21. Nasreddine ZS, Phillips NA, Bédirian V, et al. The Montreal Cognitive Assessment, MoCA: a brief screening tool for mild cognitive impairment. *J Am Geriatr Soc*. 2005;53(4):695-699. doi:10.1111/j.1532-5415.2005.53221.x

22. MoCA Cognitive Assessment. Accessed February 17, 2022. https://www.mocatest.org/

23. McRackan TR, Hand BN, Velozo CA, Dubno JR; Cochlear Implant Quality of Life Development Consortium. Cochlear Implant Quality of Life (CIQOL): development of a profile instrument (CIQOL-35 Profile) and a global measure (CIQOL-10 Global). *J Speech Lang Hear Res*. 2019;62(9):3554-3563. doi:10.1044/2019_JSLHR-H-19-0142

24. McRackan TR, Hand BN, Velozo CA, Dubno JR; Cochlear Implant Quality of Life Consortium. Validity and reliability of the Cochlear Implant Quality of Life (CIQOL)-35 Profile and CIQOL-10 Global instruments in comparison to legacy instruments. *Ear Hear*. 2021;42(4):896-908. doi:10.1097/AUD.0000000000001022

25. Byrne D, Dillon H. The National Acoustic Laboratories' (NAL) new procedure for selecting the gain and frequency response of a hearing aid. *Ear Hear*. 1986;7(4):257-265. doi:10.1097/00003446-198608000-00007

26. Tillman TW, Carhart R. *An Expanded Test for Speech Discrimination Utilizing CNC Monosyllabic Words. Northwestern University Auditory Test No. 6*. SAM-TR-66-55 [Technical report]. SAM-TR USAF School of Aerospace Medicine; 1966, pp 1-12.

27. Spahr AJ, Dorman MF, Litvak LM, et al. Development and validation of the AzBio sentence lists. *Ear Hear*. 2012;33(1):112-117. doi:10.1097/AUD.0b013e31822c2549

28. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. Routledge; 2013. doi:10.4324/9780203771587

29. Causey GD, Hood LJ, Hermanson CL, Bowling LS. The Maryland CNC Test: normative studies. *Audiology*. 1984;23(6):552-568. doi:10.3109/00206098409081538

30. Owens DK, Davidson KW, Krist AH, et al; US Preventive Services Task Force. Screening for cognitive impairment in older adults: US Preventive Services Task Force recommendation statement. *JAMA*. 2020;323(8):757-763. doi:10.1001/jama.2020.0435

31. Punch JL, Robbins AM, Myres WA, Pope ML, Miyamoto RT. Relationships among selected measures of single-channel cochlear implant performance. *Ear Hear*. 1987;8(1):37-43. doi:10.1097/00003446-198702000-00007

32. Gantz BJ, Woodworth GG, Knutson JF, Abbas PJ, Tyler RS. Multivariate predictors of audiological success with multichannel cochlear implants. *Ann Otol Rhinol Laryngol*. 1993;102(12):909-916. doi:10.1177/000348949310201201

33. Lyxell B, Andersson J, Andersson U, Arlinger S, Bredberg G, Harder H. Phonological representation and speech understanding with cochlear implants in deafened adults. *Scand J Psychol*. 1998;39(3):175-179. doi:10.1111/1467-9450.393075

34. Saunders GH, Odgear I, Cosgrove A, Frederick MT. Impact of hearing loss and amplification on performance on a cognitive screening test. *J Am Acad Audiol*. 2018;29(7):648-655. doi:10.3766/jaaa.17044

35. Kropp P, Niederberger U, Gerber WD. Prediction of verbal and numerical comprehension in patients with cochlear implants. Article in German. *Laryngorhinootologie*. 2000;79(7):388-391.

36. Heydebrand G, Hale S, Potts L, Gotter B, Skinner M. Cognitive predictors of improvements in adults' spoken word recognition six months after cochlear implant activation. *Audiol Neurootol*. 2007;12(4):254-264. doi:10.1159/000101473

37. Mosnier I, Bebear JP, Marx M, et al. Improvement of cognitive function after cochlear implantation in elderly patients. *JAMA Otolaryngol Head Neck Surg*. 2015;141(5):442-450. doi:10.1001/jamaoto.2015.129

38. Zhan KY, Lewis JH, Vasil KJ, et al. Cognitive functions in adults receiving cochlear implants: predictors of speech recognition and changes after implantation. *Otol Neurotol*. 2020;41(3):e322-e329. doi:10.1097/MAO.0000000000002544

39. Cosetti MK, Pinkston JB, Flores JM, et al. Neurocognitive testing and cochlear implantation: insights into performance in older adults. *Clin Interv Aging*. 2016;11:603-613. doi:10.2147/CIA.S100255

40. Völter C, Götze L, Dazert S, Falkenstein M, Thomas JP. Can cochlear implantation improve neurocognition in the aging population? *Clin Interv Aging*. 2018;13:701-712. doi:10.2147/CIA.S160517

41. Moberly AC, Patel TR, Castellanos I. Relations between self-reported executive functioning and speech perception skills in adult cochlear implant users. *Otol Neurotol*. 2018;39(2):250-257. doi:10.1097/MAO.0000000000001679

42. Moberly AC, Harris MS, Boyce L, et al. Relating quality of life to outcomes and predictors in adult cochlear implant users: are we measuring the right things? *Laryngoscope*. 2018;128(4):959-966. doi:10.1002/lary.26791

43. Wick CC, Kallogjeri D, McJunkin JL, et al; CI532 Study Group. Hearing and quality-of-life outcomes after cochlear implantation in adult hearing aid users 65 years or older: a secondary analysis of a nonrandomized clinical trial. *JAMA Otolaryngol Head Neck Surg*. 2020;146(10):925-932. doi:10.1001/jamaoto.2020.1585

44. Petersen RC, Lopez O, Armstrong MJ, et al. Practice guideline update summary: mild cognitive impairment: report of the Guideline Development, Dissemination, and Implementation Subcommittee of the American Academy of Neurology. *Neurology*. 2018;90(3):126-135. doi:10.1212/WNL.0000000000004826

45. Raymond MJ, Lee AC, Schader LM, Moore RH, Raol NR, Vivas EX. Practices and perceptions of cognitive assessment for adults with age-related hearing loss. *Laryngoscope Investig Otolaryngol*. 2019;5(1):137-144. doi:10.1002/lio2.339

46. Lin VYW, Chung J, Callahan BL, et al. Development of cognitive screening test for the severely hearing impaired: Hearing-Impaired MoCA. *Laryngoscope*. 2017;127(suppl 1):S4-S11. doi:10.1002/lary.26590