JAMA Otolaryngology–Head & Neck Surgery | Original Investigation

Factors Associated With Dizziness Among Patients With Vestibular Schwannoma

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IMPORTANCE Patients with vestibular schwannoma (VS) commonly present with neurological symptoms such as hearing loss, tinnitus, and dizziness. However, factors associated with dizziness at presentation are not well understood.

OBJECTIVE To evaluate the baseline features of adults diagnosed with VS associated with subjective dizziness using a validated instrument.

DESIGN, SETTING, AND PARTICIPANTS This retrospective cohort study included adults with radiologically diagnosed VS who completed vestibular testing at Washington University (St Louis, Missouri) between June 2004 and January 2025. Baseline dizziness was measured using the Dizziness Handicap Inventory (DHI).

EXPOSURES Anxiety associated with a VS diagnosis.

MAIN OUTCOMES AND MEASURES The primary outcome was severity of dizziness based on DHI score.

RESULTS A total of 109 patients were included; the mean (SD) age was 61 (14) years, 57 (52%) were female, and 52 (48%) were male. The mean (SD) DHI score was 27 (24) points. Participants with a history of anxiety had a DHI score that was 13.7 points (95% CI, 4.2-23.2 points) higher than those with no such history. For every additional point in severity of anxiety measured using the Generalized Anxiety Disorder-7 (GAD-7) scale, DHI score increased 2.6 points (95% CI, 2.0-3.3 points). After controlling for covariates, for every 1-point increase in GAD-7, DHI score increased by a mean of 1.9 points (95% CI, 1.3-2.6 points). On average, patients with a history of anxiety had a DHI score 10.6 points (95% CI, 2.4-18.7 points) higher than those with no such history.

CONCLUSIONS AND RELEVANCE This retrospective cohort study suggests a psychological association between anxiety and dizziness might exist among patients with VS that has not previously been explored. Further studies examining this association are needed in this patient population.

JAMA Otolaryngol Head Neck Surg. 2025;151(11):1057-1062. doi:10.1001/jamaoto.2025.2849
Published online October 2, 2025.

Supplemental content

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Vestibular schwannomas (VS) are benign tumors of the vestibulocochlear nerve, commonly presenting with symptoms of hearing loss, tinnitus, and dizziness. During the last 50 years, physicians have diagnosed an increasing number of patients with VS.[1] Between 1976 and 2015, the incidence rate of VS diagnoses increased from 3 to 34 cases per million per year.[2] According to Marinelli et al,[3] 1 in 500 people will develop a sporadic VS during their lifetime. This increasing incidence of VS is thought to be due to various factors, such as the increasing use of magnetic resonance imaging (MRI) examinations and the detection of smaller tumors in older patients.[4,5] The increased use of MRI has also resulted in more asymptomatic patients being diagnosed with VS.

Among patients with VS, vertigo and dizziness have been reported as 2 of the main predictors of overall quality of life and functional impairment.[6,7] The Dizziness Handicap Inventory (DHI), a patient-reported outcome measure,[8] has been widely used to quantify the severity of dizziness. Carlson et al[9] found that dizziness, as measured by the DHI, had a long-term impact on patients, even 8 years after treatment, and had an association with severity of ongoing headaches. However, this study did not evaluate the impact of objective measures such as vestibular function on the severity of dizziness. Kjaersgaard et al[10] reported that severe dysfunction and failure in at least 3 vestibular organs correlates with a higher DHI score and severity of disability, and those with a substantial loss of vestibular function are likely to have a higher DHI score. However, that

study did not assess the association between subjective clinical variables and DHI. Andersen et al[11] highlighted the association between vertigo and canal paresis or postural instability; however, their findings were limited to the use of the visual analog scale, which is not a validated tool to assess dizziness. Ermis et al[12] studied the impact of VS on dizziness and found that the presence of dizziness before stereotactic radiosurgery was associated with dizziness after radiosurgery using a binary patient-reported outcome measure. Overall, dizziness symptoms vary greatly among patients with VS. Previous studies have been limited and have not consistently evaluated presenting symptoms of dizziness and objective measures of vestibular function. Beyond measures of vestibular dysfunction, factors that potentially contribute to dizziness at baseline are not well understood in the VS population. The objectives of this study were to investigate subjective and objective baseline factors that are associated with dizziness in patients with a VS by using the DHI, a validated instrument for assessing a patient's perceived disability and severity of dizziness.

Key Points

Question What factors are associated with baseline dizziness among patients with vestibular schwannoma?

Findings This cohort study of 109 adults found an association between the severity of anxiety and dizziness among patients with unilateral vestibular schwannoma.

Meaning These findings suggest that patients with vestibular schwannoma should be evaluated for symptoms of anxiety and dizziness.

Methods

This single institutional retrospective cohort study was approved by the Washington University School of Medicine in St Louis Institutional Review Board. This study was performed following the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline. Informed consent was waived because only retrospective, deidentified data were used.

Participants

We included participants aged 18 years or older who were diagnosed with an untreated, unilateral VS between June 2004 and January 2025 and presented to Barnes-Jewish Hospital in St Louis, Missouri at any point during this period. Potential participants with VS were identified using the Slicer Dicer tool in Epic Hyperspace.[13] Key words included the following terms: *benign neoplasm of cranial nerves* (*International Statistical Classification of Diseases and Related Health Problems, Tenth Revision*, diagnosis code D33.3) and *vestibular testing*. Participants were included if they had an MRI to confirm diagnosis, completed a DHI, and underwent vestibular testing before any surgery or radiation to the tumor. Participants were excluded if they had a diagnosis of neurofibromatosis or bilateral VS. We collected baseline characteristics including demographics, clinical presentation and history, anxiety, comorbidity score using the Adult Comorbidity Evaluation-27 (ACE-27) instrument, and vestibular testing and dizziness assessments.

Demographics

The baseline demographics included sex, date of birth, date of diagnosis, age at diagnosis, body mass index (BMI), race, and type of insurance collected from the medical record. The date of diagnosis was reported as the date of the first MRI reporting the diagnosis of VS or the first mention of VS in the medical record. Age at diagnosis was calculated using the difference between a participant's date of birth and date of diagnosis. BMI was calculated as weight in kilograms divided by height in meters squared and rounded to the nearest integer. Self-reported race was coded as White or other (American Indian, Asian, Black, Native Hawaiian, Pacific Islander, and not reported) due to the small number of patients of other races. We reported on participant race for this study as part of the routine capture of demographics in clinical evaluations and because we sought to identify any baseline factors that could potentially be associated with dizziness. Insurance was coded as Medicare or private.

The DHI is a self-assessment questionnaire focused on the physical, functional, and emotional aspects of dizziness and is designed to evaluate the impact of dizziness on an individual's daily life. The DHI consists of 25 questions, each with 3 possible answers. Answers are coded as no (value = 0), sometimes (2), and yes (4). The total DHI scores range between 0 and 100 and are calculated by summing the total score, with 0 indicating no disability and 100 indicating maximum disability with regards to dizziness.[8,9]

Clinical Presentation and History

Symptoms leading to the initial MRI were captured and categorized as VS-related and non-VS-related symptoms. VS-related symptoms included tinnitus, dizziness or vertigo, imbalance or unsteadiness, facial numbness or tingling, ear fullness, hearing loss, or headache. Other factors collected in the medical history were migraine, musculoskeletal ailments, vision disturbances, and neurological ailments.

ACE-27

The ACE-27[14] is a validated comorbidity index that describes the overall severity of comorbidity by 4 categories (none, mild, moderate, or severe) based on the individual degree of organ decompensation for a variety of chronic conditions. ACE-27 scores were dichotomized to none/mild or moderate/severe.

Anxiety

We captured severity of anxiety using 2 methods in this population. Participants were coded as having anxiety if the medical record indicated they had a formal diagnosis of generalized anxiety disorder or had any mention in the medical record of anxiety state at any time before diagnosis of VS. In addition, participants completed the Generalized Anxiety Disorder-7 (GAD-7) scale, a validated tool widely used to assess severity of anxiety. GAD-7 consists of 7 items and has a total score

Table 1. Baseline Characteristics of Study Participants With Vestibular Schwannoma

Characteristic	No. (%) (N = 109)	DHI, mean (SD)	Unadjusted β coefficient (95% CI)[a]
Age, mean (SD), y	61 (14)	27 (24)	0.3 (0.0 to 0.6)
Sex			
Female	57 (52)	32 (22)	9.8 (0.9 to 18.7)
Male	52 (48)	22 (24)	1 [Reference]
Race			
White	101 (93)	28 (24)	6.6 (−10.8 to 23.9)
Other[b]	8 (7)	21 (18)	1 [Reference]
BMI			
Normal or overweight	55 (51)	26 (22)	1 [Reference]
Obesity	54 (49)	28 (26)	1.9 (−7.2 to 10.9)
Type of insurance			
Medicare	38 (35)	31 (22)	1 [Reference]
Private	71 (65)	25 (24)	−6.5 (−15.9 to 2.9)

Abbreviations: BMI, body mass index; DHI, Dizziness Handicap Inventory.

[a] β Coefficients for continuous variables represent the change in outcome for unit change in variable. For categorical variables, β coefficients represent the mean difference from the reference category.

[b] Includes 1 American Indian participant, 6 Black participants, and 1 whose race was not reported. These were grouped together due to the small number of participants.

ranging from 0 to 21, with higher scores indicating more severe anxiety. GAD-7 was administered at the time of vestibular testing.[15] Two participants did not complete the GAD-7.

Tumor Characteristics

VS characteristics were defined by the MRI examination performed at Washington University or an outside facility. The tumors were categorized by side (left or right), primarily cystic or solid, and size of tumor as measured by volumetric analysis. The tumor size was determined using MRI at diagnosis. Manual segmentation was performed by the senior author (N.D.) using the Sectra Volume Measurement tool (Sectra IDS7; Sectra). The MRI series (most commonly T1 with contrast) with the finest resolution of the VS was used. If better resolution was available on the T2 series, which is common for smaller tumors, then the T2 series was used to obtain a tumor volume. For all participants, the MRI image available was measured and reported in cubic centimeters.

Vestibular Testing

Trained audiologists performed vestibular testing at Washington University, and the first author (T.W.) extracted results from the medical record. Assessments captured during vestibular testing include video-oculography (VOG), caloric function testing, Video Head Impulse Test (vHIT), rotational chair, Vestibular Evoked Myogenic Potential (VEMP), and computerized dynamic posturography (CDP) per routine clinical protocol. Caloric function was one of the main variables assessed to determine loss of unilateral vestibular function and was treated as a continuous variable. Because many of these tests are complementary, and there was heterogeneity in the testing performed, patients were categorized into clinically meaningful groups (no vestibular dysfunction, compensated vestibular dysfunction, and uncompensated vestibular dysfunction). The audiologists categorized patients into these groups, and the senior author (N.D.) confirmed patient groups by using a global assessment of available vestibular testing, including VOG, vHIT, rotational chair, CEMP, and CDP.

Statistical Analysis

Descriptive statistics were used to describe the study population and severity of dizziness as the primary outcome measure. Continuous variables were summarized using mean and SD, whereas categorical variables were summarized as frequencies and percentages. The association between baseline factors and the primary outcome, DHI, was evaluated using linear regression and reported as β coefficients and 95% CIs. We then evaluated clinically relevant and statistically significant variables to determine which variables should be included in a multivariable regression model using backward selection; we used *t* tests to identify the variables that were statistically significant (2-sided $P < .05$). Statistical analyses were conducted using IBM SPSS Statistics for Windows, version 29.0.2.0 (IBM).

Results

Participant and Tumor Characteristics

This study included 109 participants diagnosed with VS. The mean (SD) age was 61 (14) years, ranging from 22 to 82 years. Among participants, 57 (52%) were female and 52 (48%) were male; 101 (93%) were White and 8 (7%) were of other race (including 1 American Indian participant, 6 Black participants, and 1 participant whose race was not reported). VS-related symptoms were found in 89 participants (83%) who underwent MRI testing, and the mean (SD) tumor volume was 1.5 (3.3) cm^3. There were 71 participants (65%) with private insurance. The mean (SD) score for DHI was 27 (24), ranging from 0 to 92.

Univariable Regression

In the univariable regression model, for every 10-year increase in age, there was a 3-point increase in DHI score (β = 0.3; 95% CI, 0.02-0.6 points) (**Table 1**). There was a significant association between sex and DHI. Women had on higher average DHI score than men (β = 9.8; 95% CI, 0.9-18.7 points). Participants with a history of anxiety had a higher average

Table 2. Symptoms at Presentation, Clinical Factors, Tumor Characteristics, and Vestibular Function

Category	No. (%)	DHI, mean (SD)	Unadjusted β coefficient (95% CI)
Hearing loss			
Yes	65 (61)	22 (22)	−11.4 (−20.4 to −2.4)
No	44 (39)	34 (25)	1 [Reference]
Imbalance			
Yes	27 (75)	37 (29)	13.0 (2.8 to 23.2)
No	82 (25)	24 (21)	1 [Reference]
Dizziness			
Yes	43 (39)	35 (23)	12.6 (3.7 to 21.6)
No	66 (61)	22 (23)	1 [Reference]
Tinnitus			
Yes	38 (35)	24 (23)	−4.7 (−14.2 to 4.8)
No	71 (65)	29 (24)	1 [Reference]
Headache			
Yes	9 (8)	46 (28)	20.8 (4.8 to 36.8)
No	100 (92)	25 (23)	1 [Reference]
Musculoskeletal ailments			
Yes	51 (47)	30 (25)	5.1 (−4.0 to 14.1)
No	58 (53)	25 (23)	1 [Reference]
Neurological ailments			
Yes	30 (27)	42 (25)	5.9 (−4.2 to 16.0)
No	79 (73)	24 (22)	1 [Reference]
Vision impairments			
Yes	24 (22)	37 (28)	13.1 (2.5 to 23.8)
No	85 (78)	24 (22)	1 [Reference]
Comorbidity			
None/moderate	70 (64)	24 (21)	1 [Reference]
Moderate/severe	39 (36)	32 (27)	7.5 (−1.9 to 16.8)
History of anxiety			
Yes	33 (30)	37 (22)	13.7 (4.2 to 23.2)
No	89 (82)	23 (25)	1 [Reference]
GAD-7, mean (SD)	5 (6)	27 (24)	2.6 (2.0 to 3.3)
Tumor volume, mean (SD)	1.5 (3.3)	27 (24)	−0.6 (−2.0 to 0.8)
Tumor composition			
Solid	96 (88)	27 (24)	0.3 (−14.0 to 14.0)
Cystic	13 (12)	27 (24)	1 [Reference]
Caloric function, mean (SD)[a]	44 (33)	27 (24)	−0.6 (−0.2 to 0.1)
Overall vestibular function			
No dysfunction	30 (28)	28 (28)	1 [Reference]
Compensated dysfunction	55 (50)	25 (22)	−3.0 (−13.9 to 7.8)
Uncompensated dysfunction	24 (22)	30 (23)	2.0 (−12.3 to 16.2)

Abbreviations: GAD-7, Generalized Anxiety Disorder-7; DHI Dizziness Handicap Inventory.

[a] Six patients did not have a reported value for caloric function.

DHI score (β = 13.7; 95% CI, 4.2-23.2 points) than those with no such history. For every additional point in severity of anxiety based on GAD-7 score, the DHI score increased 2.6 points (95% CI, 2.0-3.3 points) (**Table 2**; **Figure 1**). Patients presenting with hearing loss symptoms had a lower mean DHI score (β = −11.4; 95% CI, -20.4 to 2.4) than those with no hearing loss. Participants presenting with a headache had a higher DHI score (β = 20.8; 95% CI, 4.9-36.8) than participants with no headache (Table 2). Tumor volume was not associated with DHI score (β = −0.6; 95% CI, −2.0 to 3.3). Caloric function was not associated with DHI score (β = −0.6; 95% CI, −0.2 to 0.1) (**Figure 2**).

Multivariable Analysis

We performed a multivariable linear regression model with backward selection using clinically relevant variables and

variables displaying a significant association with DHI in bivariate analysis, including age at diagnosis, sex, vision impairment, severity of comorbidity, migraine, headache, hearing loss, history of anxiety, dizziness, imbalance, vestibular function, and GAD-7 score. The final model included age at diagnosis, hearing loss, imbalance, dizziness or vertigo, history of anxiety, and GAD-7 score. Among these, GAD-7 score was associated with DHI score (standardized β = 0.463), followed by history of anxiety (standardized β = 0.204) (**Table 3**).

After controlling for other variables in the model, for every 1-point increase in GAD-7 score, DHI score increased by an average of 1.9 points (β = 1.9; 95% CI, 1.3-2.6). Patients with history of anxiety had a higher DHI on average than patients with no such history (adjusted β = 10.6; 95% CI, 2.4-18.7).

Discussion

In this single-institution, retrospective cohort study of patients with VS, GAD-7 score, history of anxiety, dizziness, and unsteadiness at baseline were associated with self-perceived disability and higher DHI scores. Interestingly, anxiety had the strongest association with dizziness among patients with VS compared with other variables in the multivariable regression.

As found in studies by Stangerup et al[5] and Cioffi et al,[16] the age of onset for VS has increased, primarily shifting to patients aged 50 years or older. Female sex was associated with a greater degree of disability, similar to a previous study.[9] We found an association between headaches as an existing symptom, as well as history of migraine, with DHI score, which is consistent with previous studies evaluating the presence of headaches in this population.[9,17]

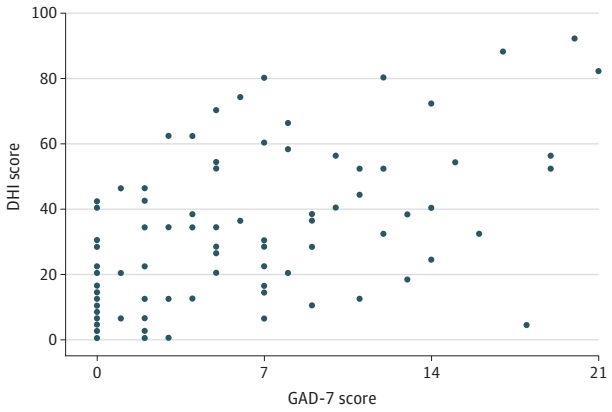
In contrast to findings from Kjaersgaard et al,[10] vestibular dysfunction was not associated with DHI score. Additionally, larger tumor size was not associated with DHI score, as found in the study by Carlson et al.[9] This finding can commonly be seen in clinical practice for patients with large tumors undergoing slow vestibular compensation, resulting in a low DHI score. Conversely, other patients with smaller tumors might have elevated DHI scores due to other factors as shown in this study, such as anxiety and headache, which were associated with DHI score.

Psychological distress has been found to have an effect on vertigo in patients with diseases and conditions affecting the vestibular system.[18-20] Although these studies have identified the association between vertigo and anxiety disorders, to our knowledge, no study to date has examined the role of anxiety in VS. This gap provides the opportunity for other VS interventions, such as mindfulness-based stress reduction.

Strengths and Limitations

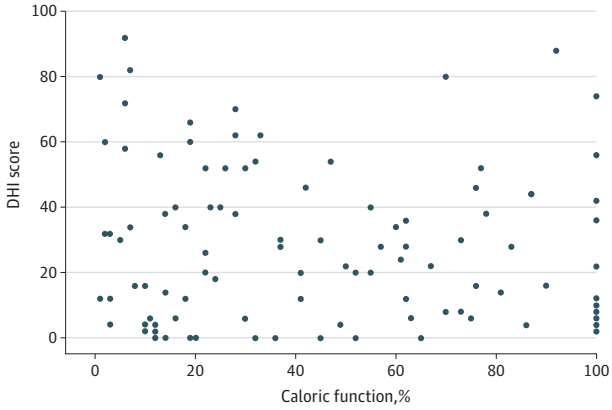
The strengths of this study include the use of the DHI as a validated instrument and objective and subjective measurements, such as vestibular testing, tumor size at time of diagnosis, age, comorbidity, and reported anxiety scores. This study also had some limitations. Although this retrospective

Figure 1. Association Between Anxiety and Dizziness



Represented as individual General Anxiety Disorder-7 (GAD-7) and Dizziness Handicap Inventory (DHI) scores.

Figure 2. Association Between Caloric Function and Dizziness



Represented as the percentage of caloric function related to Dizziness Handicap Inventory (DHI) score.

Table 3. Multivariable Analysis

	β Coefficient[a,b]	
Category	Adjusted (95% CI)	Standardized
GAD-7	1.9 (1.3 to 2.6)	0.463
History of anxiety	10.6 (2.4 to 18.7)	0.204
Hearing loss	−7.9 (−15.1 to −0.8)	−0.164
Dizziness	7.6 (0.1 to 15.1)	0.154
Imbalance	8.7 (−0.2 to 17.6)	0.153
Age	0.2 (0.0 to 0.5)	0.137

Abbreviation: GAD-7, Generalized Anxiety Disorder-7.

[a] The following variables were included in the multivariable regression model: age, sex, comorbidity, caloric function, dizziness at presentation, headache at presentation, hearing loss, imbalance, vision disturbances, history of migraines, and history of anxiety based on GAD-7 score.

[b] The final model included the following variables: GAD-7 score, history of anxiety, hearing loss, dizziness at presentation, imbalance, and age. All other variables were excluded if $P > .10$.

study had readily available information, all patients did not report to the same physician, leading to differences in documentation in the medical record. Some insurance plans do not cover all subtests within the vestibular testing, so subtests might not have been collected. Due to varying factors, such as referrals from outside hospitals and scheduling availability, the DHI assessment and vestibular testing were not collected at a consistent time point after the initial discovery of VS. Some patients with very large tumors might be underrepresented because these patients do not always undergo vestibular testing. As with other comprehensive studies in this patient population, the small sample size is a limitation of this study.

Conclusions

This cohort study found that dizziness is a significant clinical factor associated with quality of life in patients with VS. Moderate to severe dizziness (based on DHI score) was associated with severity of anxiety (based on GAD-7 score) among patients with VS. This association appeared to be the strongest compared with the associations seen with other variables. Dizziness is often unreported by referring physicians and should be assessed when suspecting a diagnosis of VS. Future studies should include anxiety in evaluation and as a factor of dizziness in patients with VS.

ARTICLE INFORMATION

Accepted for Publication: July 20, 2025.

Published Online: October 2, 2025. doi:10.1001/jamaoto.2025.2849

Author Contributions: Mr Wilson 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: Wilson, Shew, Herzog, Buchman, Piccirillo, Durakovic.
Acquisition, analysis, or interpretation of data: Wilson, Kallogjeri, Sinks, English, Jiramongkolchai, Shew, Durakovic.
Drafting of the manuscript: Wilson, Durakovic.
Critical review of the manuscript for important intellectual content: All authors.
Statistical analysis: Wilson, Kallogjeri, Durakovic.
Obtained funding: Piccirillo.
Administrative, technical, or material support: Sinks, English, Jiramongkolchai, Shew, Herzog, Buchman, Durakovic.
Supervision: Shew, Herzog, Buchman, Piccirillo, Durakovic.

Conflict of Interest Disclosures: Dr Kallogjeri reported receiving royalty payments from Washington University for the Nasal Outcome Score for Epistaxis in Hereditary Hemorrhagic Telangiectasia (NOSE-HHT) outside the submitted work. Dr Herzog reported receiving personal fees from Cochlear Ltd for serving as a consultant and member of its advisory board outside the submitted work. Dr Buchman reported receiving personal fees from Advanced Bionics, Cochlear Ltd, and Iotamotion for serving as a consultant; and grants from the National Institutes of Health's National Institute on Deafness and Other Communication Disorders outside the submitted work. Dr Piccirillo reported receiving royalty payments from Washington University for the licensing of the Sino-Nasal Outcome Tests, NOSE-HHT, and Symptoms of Nocturnal Obstruction and Related Events. No other disclosures were reported.

Funding/Support: Research reported in this publication was supported by the National Institute on Deafness and Other Communication Disorders within the National Institutes of Health, through the Otolaryngology R25 Mentored Research Pathway for Residents and Medical Students training grant (award number R25DC020706).

Role of the Funder/Sponsor: The funder had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Disclaimer: Dr Kallogjeri is the statistics editor, Dr Shew is the AI/digital health editor, and Dr Piccirillo is the editor of *JAMA Otolaryngology–Head & Neck Surgery*, but they were not involved in any of the decisions regarding review of the manuscript or its acceptance. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Data Sharing Statement: See the Supplement.

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