Laryngoscope Investigative Otolaryngology

Health-Related Quality of Life and Economic Burden of Vestibular Loss in Older Adults

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Objectives: Vestibular loss is a debilitating condition, and despite its high prevalence in older adults, the quality of life (QoL) burden of vestibular loss in older individuals has not been well-studied. This report quantifies the impact on overall QoL and identifies domains of health most affected. We hypothesize vestibular loss will be associated with impairment in diverse domains of health-related QoL.

Study Design: Prospective, case-control study.

Methods: A convenience sample of 27 patients age ≥60 years with vestibular physiologic loss was recruited from an academic neurotology clinic. The patients did not have any identifiable cause of their vestibular loss other than aging. The convenience sample was compared to an age-matched cross-sectional sample of the general US population (n = 1266). The main outcome was QoL measured by the Ontario Health Utilities Index Mark III (HUI3).

Results: Compared to the general population, patients with vestibular loss had significantly lower overall unadjusted HUI3 scores (−0.32, $p < 0.001$). Multivariate regression analysis showed vestibular loss was significantly associated with poorer performance in vision (−0.11 $p < 0.0001$), speech (−0.15, $p < 0.0001$), dexterity (−0.13, $p < 0.0001$), and emotion (−0.07, $p = 0.0065$). Adjusted aggregate HUI3 was also significantly lower for vestibular loss (−0.15, $p = 0.0105$). These QoL decrements resulted in an average loss of 1.30 Quality-Adjusted Life Years (QALYs). When using a $50,000/QALY willingness-to-pay threshold, vestibular loss was associated with a $64,929 lifetime economic burden per affected older adult, resulting in a total lifetime societal burden of $227 billion for the US population ≥60 years of age.

Conclusions: Loss of vestibular function with aging significantly decreases quality of life across multiple domains of well-being. These QoL reductions are responsible for heavy societal economic burdens of vestibular loss, which reveal potential benefits of prompt diagnosis and treatment of this condition.

Key Words: Vestibular loss, aging, health-related quality of life.

Level of Evidence: 3

INTRODUCTION

The vestibular system is integral to balance control, locomotion, and spatial navigation. Loss of vestibular function can be a debilitating condition that causes imbalance, unsteady vision, and a 12-fold increased risk of falls and fall-associated morbidity.[1] Individuals with vestibular loss have difficulty carrying out activities of daily living such as walking, climbing stairs, and driving, and these individuals report increased dependence on others, reduced productivity, and decreased life satisfaction.[2–5] As with other sensory systems, vestibular function declines with age, and older individuals are disproportionately affected by vestibular loss. Some degree of physiologic vestibular impairment occurs in 50% of older adults age ≥ 60 years,[1] and symptoms of vestibular loss such as imbalance with ambulation or unsteady vision (oscillopsia) are commonly reported by community-dwelling older adults.[6–10] The increased prevalence of vestibular loss in the older population has potentially substantial economic and societal consequences.

Despite the greater prevalence of vestibular loss in older adults and its associated functional limitations, the quality of life (QoL) burden of vestibular loss in this vulnerable population has not been well-studied. The few studies that have reported QoL outcomes considered the broader symptom of dizziness rather than specifically vestibular physiologic impairment,[7,11–15] did not have a normative-age-matched comparison group available,[11] or were conducted across a broad age range including younger age groups.[7,13,16]

In this report, we quantify the independent impact of vestibular physiologic loss on overall QoL and identify domains of health including vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain affected by this condition in a sample of older adults with vestibular loss seen in a Neurotology clinic. We compare results in this sample to QoL attainment

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Editor's Note: This Manuscript was accepted for publication 10 November 2017.

Funding: This work was supported in part by the National Institutes of Health [NIDCD K23 DC013056, NIDCD T32 DC000023].

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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DOI: 10.1002/lio2.129

among age-matched peers from the general US population. Lastly, we report the individual and societal economic burden of vestibular loss in aging adults using the difference in QoL attainment between the study sample and normative control groups.

MATERIALS AND METHODS

Study Design and Study Population

Approval for this study was obtained from the Hospital Institutional Review Board. Patients were recruited from the Otology–Neurotology practice within the Department of Otolaryngology–Head and Neck Surgery. Eligible participants were age $\geq$60 years who presented with dizziness and imbalance, and had evidence of vestibular impairment confirmed by vestibular physiologic testing. A cutoff of $\geq$60 years of age was used as a defined criteria for an older population.[17] Vestibular testing procedures consisted of standard clinical assessments including head impulse testing (HIT; either qualitative or quantitative using video-oculography), measurement of cervical vestibular-evoked myogenic potentials (cVEMP), caloric testing, and/or rotatory chair testing. The patients did not have a specific vestibular diagnosis, such as Menière's disease or benign paroxysmal positional vertigo, as this was a study of vestibular loss primarily due to advanced age. Demographic, socioeconomic, and medical history factors were collected for each patient through a medical chart review.

Patients in this study completed a paper-based QoL survey. The survey included the Health Utilities Index Mark 3 (HUI3) questionnaire, which is a 15-item, population-based, validated health utility instrument that measures the respondent's general health status and health-related quality of life along 8 specific domains of function: vision, hearing, speech, ambulation, dexterity, emotion, cognition, and pain.[18] It has been used extensively in health economic analyses, including studies of cochlear implantation[19,20] and bilateral vestibular deficiency in younger adults.[21] In the present study, each respondent's individual domain and overall health utility were calculated using methods prescribed for analysis of HUI3 data,[18] yielding scores ranging from 1 ("perfect health") to 0 ("death") on the individual domains and 1 ("perfect health") to -0.371 (a state "worse than death") on the overall index. The unit for health utility from the HUI3 is the quality-adjusted life year (QALY).

Normative age-matched data from the general US population was collected from the 2002–2003 Joint Canada/United States Survey of Health (JCUSH), which is a cross-sectional random-digit-dialed telephone survey conducted in Canada and the United States, administered via a computer-assisted telephone interview (CATI).[22] The HUI3 is also administered as part of JCUSH. A total of 8,145 people of all ages took part in JCUSH, of which 5,859 participants were US residents. Of these, 1,369 were at least 60 years of age at time of study. Of the eligible adults, 104 (7.6%) participants did not complete the HUI3 questionnaire, resulting in a sample size of 1,265 participants. There were no significant differences between included and excluded participants in the HUI3 survey with respect to gender or race. Included participants, however, were more likely to be younger and single.

Assessment of Comorbidities

A history of smoking was defined in JCUSH based on smoking greater than 100 cigarettes in one's lifetime, and in patients based on a positive smoking history ascertained from the medical record. Hypertension was defined in JCUSH based on responding yes to the question "Have you ever been told by a doctor or other health professional that you have high blood pressure, also called hypertension?" and in patients based on a diagnosis of hypertension in the medical record. Diabetes mellitus was defined in JCUSH based on responding yes to the question "Have you ever been told by a doctor or other health professional that you have diabetes?" and in patients based on a diagnosis of diabetes mellitus in the medical record. Vision loss was defined in JCUSH as a positive response to the question "Do you have problems with vision (whether corrected or uncorrected with glasses or lenses)?" and in patients based on a diagnosis of vision loss from the medical record. Hearing loss was defined in JCUSH based on a positive response to the question "Do you have difficulty hearing (whether corrected or uncorrected with hearing aids) and in patients based on a diagnosis of hearing loss (either self-reported, or PTA $>$ 25 dB in the better-hearing ear) ascertained from the medical record. A history of stroke was defined in JCUSH based on a positive response to the question "What condition or health problem causes you to have difficulty?" with the patient's answer as "Stroke problem." JCUSH did not probe directly about a stroke history, but rather a history of stroke was ascertained based on a participant having difficulty in their daily life that they attributed to a history of stroke. As such, 481 individuals in JCUSH were missing data for the stroke variable. We carried out sensitivity analyses including and excluding the stroke variable from analyses to evaluate the impact of these missing data. In general the findings changed very little; therefore we included history of stroke in all analyses.

Discounting and Time Horizon

Total individual QALYs lost due to vestibular loss were calculated and averaged across all study patients by compounding the yearly adjusted health utility loss associated with vestibular loss across an individual's remaining exact age life expectancy stratified by gender.[23] The discount rate is the factor by which individuals preferentially value costs and benefits incurred in the present to those incurred in the future (e.g., one would rather receive $100 today than $100 dollars a year from now). A discount rate of 3% was utilized in all base QALY estimates, as it represents the average US government's borrowing rate, which has been argued as the most appropriate intragenerational discounting metric for use in cost-benefit analyses.[24,25] In this case, a 3% discount rate implies that the magnitude of the annual QALY losses associated with vestibular loss (and conversely potential benefits from restoring vestibular function) will decrease with every subsequent year by a factor of 1/1.03 of the prior year's value.

Perspective

Following collection of individual health-utility data, a societal perspective analysis was performed to calculate the overall economic burden of vestibular loss using a commonly accepted $50,000 Willingness-to-Pay (WTP) threshold to gain one QALY.[26]

Economic Burden and Sensitivity Analysis

The total economic burden of vestibular loss resulting from the above QALY loss was calculated for the total patient study group and stratified across three age categories, 60–69 years, 70–79 years, and $\geq$80 years. The study sample's QALY losses and associated economic burden was then generalized to the overall susceptible US population 60 years of age and older using an average of literature-derived prevalence rates of symptomatic vestibular vertigo (from which we expect our study

TABLE I.
Quality of Life Attainment in Patients with Vestibular Loss by Demographic and Medical History Factors

Characteristic	Vestibular Loss (n = 27)		General Population (n = 1265)	
	N (%)	HUI3 Mean (SE)*	N (%)	HUI3 Mean (SE)*
Gender				
Male	10 (37.0)	0.53 (0.35)	489 (38.7)	0.81 (0.25)
Female	17 (63.0)	0.44 (0.32)	776 (61.3)	0.77 (0.27)
Age				
60–69 years	6 (22.2)	0.44 (0.41)	580 (45.8)	0.82 (0.24)
70–79 years	12 (44.4)	0.54 (0.34)	481 (38.0)	0.79 (0.25)
≥80 years	9 (33.3)	0.40 (0.28)	204 (16.1)	0.69 (0.30)
Race				
Non-Hispanic White	21 (80.8)	0.41 (0.34)	1000 (82.0)	0.80 (0.25)
Non-Hispanic Black	4 (15.4)	0.70 (0.21)	93 (7.6)	0.68 (0.32)
Hispanic	NA	NA	61 (5.0)	0.72 (0.30)
Asian	NA	NA	21 (1.7)	0.87 (0.21)
Other	1 (3.8)	0.82 (0.00)	4 (3.6)	0.74 (0.28)
Marital Status				
Single	NA	NA	58 (4.6)	0.77 (0.26)
Married	2 (8.0)	0.10 (0.28)	606 (47.9)	0.83 (0.24)
Widowed	17 (68.0)	0.53 (0.34)	411 (32.5)	0.73 (0.29)
Divorced	6 (24.0)	0.35 (0.23)	149 (11.8)	0.78 (0.25)
Unknown	NA	NA	41 (3.2)	0.84 (0.21)
History of Diabetes				
Yes	8 (29.6)	0.54 (0.32)	177 (15.7)	0.67 (0.30)
No	19 (70.4)	0.44 (0.34)	953 (84.3)	0.80 (0.25)
History of Hypertension				
Yes	21 (77.8)	0.44 (0.34)	639 (50.7)	0.76 (0.28)
No	6 (22.2)	0.57 (0.31)	621 (49.3)	0.82 (0.23)
History of Stroke†				
Yes	3 (11.1)	0.29 (0.17)	26 (3.3)	0.28 (0.27)
No	24 (88.9)	0.50 (0.34)	758 (96.7)	0.72 (0.28)
History of Smoking				
Yes	15 (55.6)	0.44 (0.38)	651 (51.8)	0.79 (0.26)
No	12 (44.4)	0.51 (0.25)	606 (48.2)	0.79 (0.26)
History of Hearing Loss‡				
Yes	18 (66.7)	0.52 (0.27)	122 (9.6)	0.55 (0.29)
No	9 (33.3)	0.38 (0.42)	1143 (90.4)	0.81 (0.24)
History of Vision Loss§				
Yes	11 (40.7)	0.46 (0.33)	1006 (88.8)	0.77 (0.27)
No	16 (59.3)	0.48 (0.34)	127 (11.2)	0.78 (0.27)

*Health Utilities Index measured using Mark III transforms.
†481 participants were missing data about a history of stroke, given how the variable was coded, see text for details.
‡History of hearing loss assessed by average pure-tone hearing threshold (>25 dB) in the vestibular loss group and by participant response to presence of self-reported or diagnosed hearing problems in the Joint Canada/United States Survey of Health
§History of vision loss assessed by presence of ophthalmologic comorbidities in the vestibular loss group and by participant response to presence of self-reported or diagnosed vision problems in the Joint Canada/United States Survey of Health
HUI3, Health Utilities Index Mark III; NA, not applicable; SE, standard error

patients were drawn),[6–8,10] relative-prevalence weights by decade of age among US adults,[1] and the size of the US population[27] stratified by above age categories. Base case results were calculated for each age group using a 3% discount rate, a $50,000 WTP threshold, a weighted symptomatic vestibular loss prevalence of 8%, and an annual QoL decrease equivalent to the vestibular loss coefficient derived from the adjusted generalized linear model of overall HUI. Sensitivity analyses were performed by varying these four parameters.

Statistical analysis

Baseline demographic and medical history factors (Table I) were characterized by mean and standard error for continuous variables and by frequency distributions and percentage of total for categorical variables. Respondents' overall health states were calculated using the prescribed methodology provided for the HUI3 instrument.[16] Baseline differences in health utilities were explored using a multivariable generalized linear model, allowing for response variables that have both Gaussian and

TABLE II.
Characteristics of Subjects with Vestibular Loss.

Participant	Age (years)	Gender	Bilateral*	Basis for Diagnosis†
1	60	Male	Yes	HIT abnormal AU, absent cVEMP AU
2	64	Female	Yes	HIT abnormal AU, absent cVEMP AS
3	67	Female	No	HIT abnormal AS
4	67	Male	No	HIT abnormal AS
5	67	Female	Yes	HIT abnormal AU, caloric weakness AS
6	69	Female	Yes	Caloric weakness AS, absent cVEMP AU
7	70	Female	No	HIT abnormal AS, absent cVEMP AD
8	70	Male	Yes	Rotatory chair testing abnormal AU
9	71	Female	Yes	Absent cVEMP AU
10	72	Female	Yes	HIT abnormal AU
11	74	Female	Yes	HIT abnormal AU
12	74	Female	Yes	HIT abnormal AU
13	77	Male	Yes	HIT abnormal AU, caloric weakness AS, absent cVEMP AS
14	77	Male	Yes	HIT abnormal AS, caloric weakness AS, absent cVEMP AD
15	78	Female	Yes	HIT abnormal AU, absent cVEMP AS
16	78	Female	Yes	HIT abnormal AU, no caloric response AS, absent cVEMP AU
17	79	Male	No	HIT abnormal AU
18	79	Male	Yes	Caloric weakness AU, absent cVEMP AU
19	80	Female	Yes	HIT abnormal AU
20	83	Male	No	HIT abnormal AS
21	84	Female	Yes	HIT abnormal AU
22	84	Female	Yes	HIT abnormal AU
23	86	Male	Yes	HIT abnormal AU, absent cVEMP AD
24	87	Female	Yes	HIT abnormal AU
25	87	Female	No	HIT abnormal AU, absent cVEMP AU
26	87	Male	Yes	HIT abnormal AU, absent cVEMP AU
27	87	Female	Yes	HIT abnormal AU
Overall	**76**	**63% Female**	**78% Bilateral**	

*Bilateral vs unilateral vestibular loss.
†For unilateral caloric weakness, inter-aural asymmetry $> 20\%$, for bilateral caloric weakness, total slow phase velocity < 20 degrees/second.
AD, right ear; AS, left ear; AU, both ears; cVEMP, cervical vestibular-evoked myogenic potential; HIT, head impulse testing

non-Gaussian distributions. Covariates included demographic (age, gender, race, marital status) and clinical characteristics (history of hypertension, diabetes, stroke, smoking, hearing loss, and vision loss). STATA 13 (Stata Corp, College Station, TX) was used for all statistical analyses.

RESULTS

Demographic and clinical characteristics of the vestibular loss patient and general population groups are shown in Table I. The mean age and age ranges for the study and control groups was 76.3 (60–87) and 71.4 (60–85) years, respectively. Patients in the study group in general had greater comorbidity relative to the general population, with higher prevalences of diabetes, hypertension, stroke, smoking, and hearing loss. For most demographic and all comorbidity factors, the patient population had a lower HUI3 mean score. All of the patients in the study group had physiologic evidence of vestibular hypofunction that was not attributable to a specific diagnosis other than age. There were 21 (78%) patients with bilateral vestibular loss (BVL) and 6 (22%) patients with unilateral vestibular loss (UVL) in the patient group (Table II).

There was a 100% response rate for the HUI3 questions among patient respondents. Mean unadjusted HUI3 overall and domain-specific scores of study sample versus general population controls are shown in Figure 1. The overall HUI score was 0.47 among patients (on a scale from -0.371 to 1 as described previously) compared to 0.79 among age-matched general population controls. Statistically significant differences between patient and control groups were observed for overall score ($p < 0.001$), and for specific domains including vision ($p < 0.002$), hearing ($p < 0.001$), speech ($p < 0.001$), ambulation ($p < 0.001$), dexterity ($p < 0.001$), and emotion ($p < 0.001$) in unadjusted comparisons. Table III reports results of a multivariable generalized linear model analysis of variables associated with overall HUI3 score. After adjusting for gender, age, race, marital status, history of diabetes, hypertension, stroke, smoking, hearing loss, and vision loss, vestibular loss was responsible for a 0.15 decrease in overall health utility ($p = 0.0105$). Covariates significantly associated with a

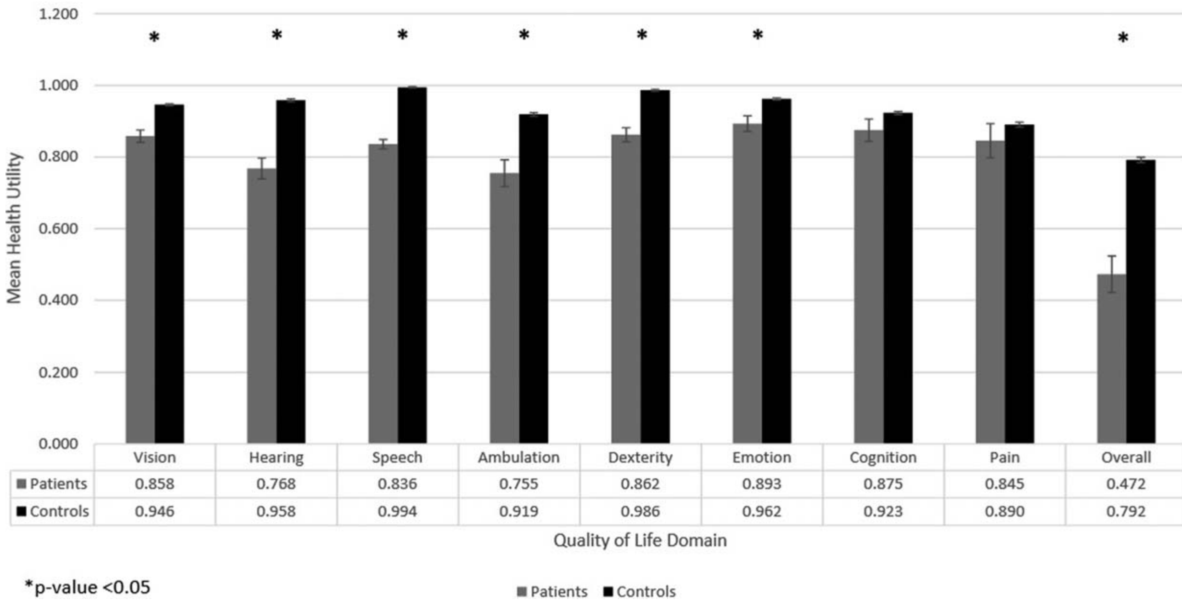

Fig. 1. Mean unadjusted HUI3 domain and overall scores for patients with vestibular loss and the general population

decreased overall HUI score included age ≥80 years (−0.07, $p = 0.0253$), non-Hispanic Black race (−0.10, $p = 0.0054$), Hispanic race (−0.12, $p = 0.0087$), history of diabetes (−0.08, $p = 0.0014$), stroke (−0.36, $p < 0.0001$), vision loss (−0.07, $p = 0.0075$), and hearing loss (−0.18, $p < 0.0001$). A marital status of "married" correlated with a significantly increased overall HUI score (0.12, $p = 0.0110$).

Table IV presents results of multivariate generalized linear models on the association of vestibular loss with individual HUI domains, adjusted for the same variables as above. Statistically significant declines in domain-specific health-utility due to vestibular loss were observed with respect to vision (−0.11, $p < 0.0001$), speech (−0.15, $p < 0.0001$), dexterity (−0.13, $p < 0.0001$), and emotion (−0.07, $p = 0.0065$). Alternatively, vestibular loss was associated with a significant increase in domain-specific health-utility with respect to hearing (0.04, $p = 0.0440$).

Lifetime QALY losses for the patient population were then calculated by discounting the adjusted 0.15 decrease in health utility (in QALY units) associated with vestibular loss from the above model across the remaining life-expectancy of each study participant, at an annual discount rate of 3% (Table V). This resulted in a total of 27.51 QALYs lost across the expected remaining lifetimes of the study population. This total number of QALYs was divided by the number of study patients (N = 27) yielding an average 1.30 lifetime QALYs lost per individual.

Assuming a $50,000/QALY WTP, the average lifetime economic burden of vestibular loss per affected older adult stratified into three age categories was $91,241, $71,698, and $38,363 for 60–69 years, 70–79 years, and ≥80 years of age, respectively (Table VI). When aggregated across the entire susceptible US population, these estimates resulted in a lifetime societal burden of $106 billion, $79 billion, and $41 billion across each of the above age groups, respectively. When combined across all three age groups, the total lifetime economic burden of vestibular loss per affected older individual was $64,929, resulting in an aggregate $227 billion societal burden of vestibular loss in older adults.

Sensitivity analyses for the lifetime economic burden of vestibular loss per affected older adult ranged from $32,465 to $97,394 and were most sensitive to changes in health utility loss and WTP thresholds (Table VI). Altering these parameters yielded a societal lifetime economic burden of vestibular loss ranging from $113 to $404 billion.

DISCUSSION

These analyses offer evidence of a strong association between vestibular loss and poor QoL outcomes in a sample of older adults with symptomatic and idiopathic vestibular loss seen in a Neurotology clinic. Only one study has previously published the QoL impact of vestibular impairment using the HUI3 survey.[21] Although focused on a considerably younger patient population, the authors of that study reported mean HUI3 scores of 0.39 and 0.63 for BVL and UVL respondents, respectively. Given the predominance of BVL patients in our study population, our mean score of 0.47 corroborated these findings. A mean HUI3 score of 0.47 is classified as severe disability by HUI3 criteria[28] and corresponds to a similar level of QoL impairment as present in individuals suffering from Parkinson's disease (0.45)[29] or untreated osteoarthritis (0.46).[30] Our study suggests that while vestibular loss may be overlooked as a benign chronic condition, it is associated with a pervasive negative impact on health-related quality of life in older individuals.

Moreover, our results demonstrate that vestibular loss has a significant and independent impact on QoL

TABLE III.
Multivariable Adjusted Generalized Linear Model on the Association of Overall HUI3 Score with Vestibular Loss.

	Health Utilities Index Mark III Overall Score†		
Variable	Coefficient	95% Confidence Interval	*P*-Value
Vestibular Loss	−0.15	−0.26, −0.03	0.0105
Female	−0.01	−0.06, 0.04	0.7558
Age			
65–69 years	ref*	ref*	ref*
70–79 years	−0.01	−0.05, 0.04	0.8075
≥80 years	−0.07	−0.13, −0.01	0.0253
Race			
Non-Hispanic White	ref*	ref*	ref*
Non-Hispanic Black	−0.10	−0.17, −0.03	0.0054
Hispanic	−0.12	−0.21, −0.03	0.0087
Asian	0.13	−0.10, 0.37	0.2684
Other	−0.03	−0.14, 0.08	0.5602
Marital Status			
Single	ref*	ref*	ref*
Married	0.12	0.03, 0.22	0.0110
Widowed	0.07	−0.03, 0.17	0.1729
Divorced	0.08	−0.02, 0.19	0.1276
Diabetes	−0.08	−0.13, −0.03	0.0014
Hypertension	−0.01	−0.05, 0.03	0.7240
Stroke	−0.36	−0.47, −0.25	<0.0001
Smoking	−0.02	−0.06, 0.03	0.4469
Vision Loss‡	−0.07	−0.12, −0.02	0.0075
Hearing Loss§	−0.18	−0.24, −0.12	<0.0001

*Reference group
†Health Utilities Index measured using Mark III transforms.
‡History of vision loss assessed by presence of ophthalmologic comorbidities in the vestibular loss group and by participant response to presence of self-reported or diagnosed vision problems in the Joint Canada/United States Survey of Health.
§History of hearing loss assessed by average pure-tone hearing threshold (>25 dB) in the vestibular loss group and by participant response to presence of self-reported or diagnosed hearing problems in the Joint Canada/United States Survey of Health.

TABLE IV.
Multivariable Adjusted Generalized Linear Models on the Association of Vestibular Dysfunction with Individual HUI3 Domains.

	Vestibular Dysfunction		
Outcome Variable*	Coefficient	95% Confidence Interval	P Value
Vision	−0.11	−0.15, −0.07	<0.0001
Hearing	0.04	0.00, 0.08	0.0440
Speech	−0.15	−0.18, −0.11	<0.0001
Ambulation	−0.08	−0.17, 0.01	0.0672
Dexterity	−0.13	−0.19, −0.08	<0.0001
Emotion	−0.07	−0.13, −0.02	0.0065
Cognition	0.01	−0.06, 0.08	0.8041
Pain	0.05	−0.06, 0.17	0.3783

HUI3, Health Utilities Index Mark III.
*All models adjusted for age, gender, race, marital status, history of diabetes, hypertension, and stroke.

TABLE V.
Expected Lifetime HUI Loss Associated with Vestibular Loss in Older Adults.

Participant	Years to Life Expectancy*	Expected Lifetime HUI Loss† (QALYs)
1	21.4	2.26
2	21.0	2.23
3	18.6	1.94
4	18.6	0.69
5	16.1	1.80
6	18.6	2.03
7	16.3	1.82
8	14.1	1.61
9	15.6	1.75
10	14.9	1.68
11	13.5	1.55
12	13.5	1.54
13	10.9	1.63
14	9.7	1.13
15	10.8	1.26
16	10.8	1.26
17	8.6	1.01
18	8.6	0.97
19	10.2	1.19
20	6.7	0.90
21	7.4	0.86
22	7.4	0.86
23	5.4	0.61
24	6.0	0.69
25	5.0	0.42
26	6.0	0.69
27	6.0	0.69
Total	321.8	35.06
Average	11.9	1.30

QALYS, Quality-Adjusted Life Years; HUI, Health Utilities Index
*Derived using US Social Security Administration's Exact Age Actuarial Life Expectancy Tables stratified by gender, http://www.ssa.gov/oact/STATS/table4c6.html.
†Using an annual HUI loss of 0.15 at a discount rate of 3% across the years to life expectancy

after adjusting for a wide array of variables, including cardiovascular risk factors, vision loss, and hearing loss. The 0.15 decrease in mean adjusted HUI3 score associated with vestibular loss is the third largest QoL reduction observed in our study, behind stroke (−0.36) and clinically significant hearing impairment (−0.18). To further contextualize the magnitude of the QoL burden of vestibular loss, this impairment is equivalent to aging 27 years based on an average HUI3 decrease of 0.054 per decade of life.[31]

Individual HUI3 domain scores reveal that the QoL impact of vestibular loss in older adults occurred not only in the expected domains of "vision" and "ambulation," but also in "speech," "dexterity," and "emotion" domains of health. Prior studies support a link between vestibular impairment and emotional health. Vestibular symptoms (specifically dizziness and

TABLE VI.
Economic Burden of Vestibular Loss in Older Adults and Sensitivity Analysis

	Symptomatic Vestibular Loss Prevalence*	Affected Population†	Average QALYs Lost‡	Population QALYs Lost§	$/QALY#	Individual Burden‖	Societal Burden (billion)¶
Base Case							
60–69 years	0.07	1,164,166	1.82	2,124,388	$50,000	$91,241	$106.22
70–79 years	0.09	1,105,494	1.43	1,585,227	$50,000	$71,698	$79.26
>=80 years	0.11	1,077,104	0.77	826,426	$50,000	$38,363	$41.32
Total	0.08	3,346,764	1.30	4,346,050	$50,000	$64,929	$226.80

	Base Estimate	Range of Estimate (Lowest to Highest)	60–69 years (Base $91,241)	70–79 years (Base $71,698)	>=80 years (Base $38,363)	Overall Individual Burden (Base $64,929)	Societal Burden (Base $226.80 billion)
Sensitivity Analysis							
Variables							
Discount rate	3%	0–6	$72,547-$118,375	$61,571-$84,994	$34,781-$42,583	$55,080-$78,275	$189.99-$277.63
Annual HUI Loss	0.15	0.10-0.20	$65,827-$131,654	$52,382-$104,764	$30,576-$61,151	$48,101-$96,202	$167.47-$334.95
Average Prevalence	0.08	0.07-0.10*	Unchanged	Unchanged	Unchanged	Unchanged	$283.10-$404.42
$/QALY	$50,000	$25,000-$75,000#	$45,620-$136,861	$35,849-$107,546	$19,182-$57,545	$32,465-$97,394	$113.40-$340.20

Abbreviations: QALY, Quality-Adjusted Life Year
*Using an average of literature-derived prevalence of vestibular vertigo with relative age-category weights from Agrawal et al (2009).
†Derived using 2013 US Census data stratified by age; www.census.gov.
‡Using an annual health-utility loss of 0.15 at a discount rate of 3% across the years to life expectancy in the vestibular loss study group
§Product of discounted average QALYs lost and affected population
#Using highly conservative Willingness-to-Pay (WTP) thresholds derived from Hirth et al. (2000).
‖Lifetime Economic Burden of vestibular loss per Affected Individual, product of Population QALYs Lost and $/QALY divided by Affected Population
¶Lifetime Societal Burden of vestibular loss, product of Population QALYs Lost and $/QALY

vertigo) have been associated with social isolation, reduced autonomy, and difficulty performing activities of daily living in older adults, likely contributing to the emotional burden of these symptoms.[7,32,33] Additionally, a recent epidemiologic study found that individuals with vestibular vertigo had a three-fold increased odds of depressive symptoms, anxiety, and panic disorder than the general US population in adjusted analyses.[34] An association between vestibular function and dexterity is supported by recent anatomic studies demonstrating vestibular inputs into central motor control centers such as the basal ganglia,[35] and epidemiologic studies showing an association between vestibular function and fine motor tasks.[36] The association between vestibular function and speech is more elusive, and may reflect the general link with motor control, and/or neural pathways that remain to be elucidated.

The overall low QoL attainment among older adults with vestibular loss carries significant individual and societal economic implications. Even without considering the economic consequences of reduced productivity (study participants were assumed to be out of the labor force) or health expenditures to treat their vestibular symptoms, vestibular loss was associated with an average $64,929 loss in individual welfare over an 11.9 year age life expectancy for our study population. The authors of a recent study also determined an estimated mean annual economic burden of $13,019 and $3531 for BVL and UVL patients, respectively.[21] Although the patient population was different as described previously, these approximations support the average $5,456 annual loss in individual welfare determined in this report. The resultant $227 billion aggregate economic burden may represent an opportunity to considerably reduce health care costs through timely diagnosis and treatment of vestibular loss.[37]

Several limitations exist in this study, including the small sample size for the study group. The large effect size of the QoL reduction and statistical significance of the results, even after adjusting for a wide array of confounding variables, however, mitigates some of these concerns. Additionally, the use of cross-sectional data in this analysis precludes causal inference and allows only for the determination of associations between QoL attainment and vestibular loss. Furthermore, relying on patient self-reporting introduces a source of response bias due to variability in understanding of the questionnaires and the subjective nature of participants' symptoms. Although estimates of vestibular loss prevalence and incidence have been computed in several recent publications,[6–8,10] the absence of large-scale, high-quality epidemiological data that are based on objective, specific assessments of vestibular function makes it difficult to determine how well our study population represents the spectrum of health-related quality of life among older individuals with symptomatic vestibular loss. This study population was also not a random sample, and therefore, the calculated lifetime societal burden of vestibular loss aggregated across the entire US population may not accurately represent the effects of vestibular loss in the general geriatric population. Finally, vestibular function was not measured in JCUSH, and our analyses assumed a zero prevalence, which if anything would have conservatively biased our results. Further limitations of the JCUSH data have been published previously.[38]

CONCLUSION

Our results demonstrate that age-related vestibular loss among patients presenting to a Neurotology clinic was associated with a 0.15 reduction in HUI3 score, which corresponds to a loss of 1.30 quality-adjusted life years. These data suggest that loss of vestibular function in older individuals can confer a significant decrement in quality of life, and is associated with substantial societal cost. Further studies are needed to measure the benefits of vestibular therapy from both the individual and societal perspective.

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