JDI Journal of Diabetes Investigation Open access
Official Journal of the Asian Association for the Study of Diabetes
ORIGINAL ARTICLE

Impact of vision and hearing impairments on risk of cardiovascular outcomes and mortality in patients with type 2 diabetes: A nationwide cohort study

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Keywords
Diabetes, Hearing impairment, Vision impairment

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J Diabetes Investig 2022; 13: 515–524

doi: 10.1111/jdi.13689

ABSTRACT

Aims/Introduction: The purpose of this study was to investigate the impact of vision and hearing impairments on the risk of adverse cardiovascular outcomes and mortality in patients with type 2 diabetes using a nationwide longitudinal cohort.

Materials and Methods: We enrolled 771,128 patients with type 2 diabetes who underwent the National Health Screening Program in 2009. We carried out Cox proportional hazards regression analyses to calculate the hazard ratios (HR) of myocardial infarction (MI), stroke, and mortality in those with or without vision and hearing impairments. Subgroup analyses of patients stratified by age, sex and diabetic retinopathy were carried out.

Results: Diabetes patients with either vision or hearing impairment showed higher risk of MI, stroke or death compared with those without. Among the combinations of impairments, patients with both vision and hearing impairments had the highest risk for MI (adjusted HR [aHR] 1.362, 95% confidence interval [CI] 1.252–1.481) and mortality (aHR 1.591, 95% CI 1.532–1.651). Those with only vision impairment showed higher risk of MI (aHR 1.324, 95% CI 1.275–1.375 and aHR 1.117, 95% CI 1.066–1.170, respectively), stroke (aHR 1.318, 95% CI 1.276–1.362 and aHR 1.134 95% CI 1.089–1.180, respectively) and mortality (aHR 1.417, 95% CI 1.390–1.446 and aHR 1.163, 95% CI 1.135–1.191, respectively) compared with those with only hearing impairment.

Conclusions: Vision and hearing impairments are independently important risk factors for adverse cardiovascular events and mortality in patients with type 2 diabetes. Vision and hearing impairments synergistically increased the risk of MI and all-cause deaths, but not stroke. In addition, in patients aged <65 years, the HR of vision impairment was higher than those with vision and hearing impairments.

INTRODUCTION

Patients with type 2 diabetes have an increased risk of cardiovascular diseases and mortality[1–6]. Other risk factors, including smoking, high blood pressure, abnormal cholesterol levels and obesity, can increase the risk of cardiovascular diseases and mortality in patients with type 2 diabetes[7].

Received 10 June 2021; revised 23 September 2021; accepted 3 October 2021

Diabetes causes vascular and neuropathic complications resulting in various impairments. The percentage of patients with diabetes who reported vision impairment and hearing impairment were 5–17%[7,8] and 21%[9], respectively, in previous epidemiological studies. Vision impairment is largely associated with diabetic retinopathy, a well-established microvascular complication of diabetes[10,11]. Hearing impairment is a less-established complication, which might be caused by

microvascular and neuropathic complications of the inner ear[9,12–14]. These sensory impairments might not only indicate poor vascular health, but also have a negative impact on diabetes control and other morbidities leading to cardiovascular diseases and higher mortality in patients with diabetes[15–19].

Although diabetic retinopathy, one of the main causes of vision impairment in patients with diabetes, has been associated with high cardiovascular diseases and mortality[15–17,19], only limited data are available on the role of vision impairment as a risk factor for cardiovascular diseases and mortality in patients with diabetes[11,18]. Furthermore, there are no reports on the impact of hearing impairment or the combination of vision and hearing impairments on these outcomes.

Therefore, in the present study, a nationwide cohort of patients with type 2 diabetes was established to investigate the impact of vision and hearing impairments on the risk of myocardial infarction (MI), stroke and all-cause mortality.

METHODS

Data source

The present population-based cohort study was based on the Korean National Health Information Database (KNHID) collected by the Korean National Health Insurance Service (KNHIS). The KNHIS requires all nationals to enroll in the system and covers 97% of the Korean population. The KNHID includes comprehensive health-related information: demographics (anonymized code for each individual, age, sex, socioeconomic variables, household income level etc.) and medical data based on medical claims (diagnostic codes by the International Classification of Diseases 10th revision [ICD-10], admission and ambulatory care, treatment procedures, and prescription records).

KNHIS also delivers the National Health Screening Program (NHSP) to all workplace subscribers, their dependents and to all Koreans aged >40 years at least every 2 years[20]. The NHSP includes anthropometric data, visual acuity measurement, pure-tone audiometric testing, blood pressure (BP), basic laboratory examinations (fasting glucose, total cholesterol etc.) and a standardized self-reporting questionnaire (medical history and health-related lifestyle factors, including smoking habits, alcohol consumption and physical exercise).

Korea also has a National Disability Registry (NDR), which classifies people with disabilities into several graded groups based on medical criteria. The National Pension Service reviews the medical records from certified ophthalmologists or otologists before registering a patient in the NDR. In the NDR, visual disability is classified into six grades depending on the visual acuity and visual field (Table S1). Hearing disability is also categorized into six grades (Table S2)[21].

All-cause mortality data were extracted from the Korean National Statistical Office. This study was approved by the institutional review board of the Yeouido St. Mary's Hospital, Seoul, Korea (SC20ZESI0142), which waived consent from individual patients, because we used publicly open and anonymized data. Our research adhered to the tenets of the Declaration of Helsinki.

Study population and definitions

In the study, we screened 926,648 people with type 2 diabetes who had undergone NHSP examination in 2009 (index date; Figure 1). Participants with a history of MI or stroke, defined as those who had claims data with ICD-10 codes for MI (I21, I22) or stroke (I63, I64) between 1 January 2002 and 31 December 2008 were excluded. The study participants were followed until 31 December 2018.

Type 2 diabetes was defined as the following: (i) at least one claim per year with E11–E14 (ICD-10 codes) and at least one claim per year with prescription for antidiabetic medication (sulfonylureas, metformin, meglitinides, thiazolidinediones, dipeptidyl peptidase-4 inhibitors, α-glucosidase inhibitors or insulin); or (ii) a fasting glucose level ≥126 mg/dL[22,23]. Diabetic retinopathy was defined using the ICD-10 code (H360) in patients with type 2 diabetes.

Vision impairment was defined as having any grade of visual disability classification in the NDR or visual acuity worse than 20/40 in both eyes. Hearing impairment was defined as having any grade of hearing disability classification in the NDR or impaired hearing (pure-tone average ≥40 dB) on pure-tone audiometric testing in at least one ear.

The end-points of the present study were newly diagnosed MI, stroke or all-cause mortality, whichever came first. MI was defined using ICD-10 codes (I21 or I22) during hospitalization or these codes being claimed at least twice. Stroke was defined using ICD-10 codes (I63 or I64) during hospitalization with claims for brain magnetic resonance imaging or brain computed tomography[22].

Smoking habit was categorized as non-smoker, ex-smoker or current smoker. Alcohol drinking was classified into no alcohol, mild alcohol (<30 g per day) or heavy alcohol (≥30 g per day). An annual household income level in the lower 25% was defined as low income. Regular exercise was defined as carrying out moderate physical activity for ≥30 min, five or more times a week or strenuous physical activity for ≥20 min, three or more times a week. Participants' body mass index (BMI) was calculated as weight (kg) divided by the square of height (m^2). Systolic and diastolic BP were measured in a seated position after ≥5 min rest. Serum glucose and total cholesterol levels were measured with blood samples collected after an overnight fasting.

Comorbidities were defined based on the combination of KNHID claims data within 1 year before the index date and NHSP results. Hypertension was defined as ICD-10 code for hypertension (I10–I13 and I15) and at least one prescription for antihypertensive medication per year, or as systolic BP ≥140 mmHg or diastolic BP ≥90 mmHg. Dyslipidemia was defined as at least one prescription claim of lipid-lowering medications per year under the ICD-10 code for dyslipidemia (E78) or as serum total cholesterol level ≥240 mg/dL.

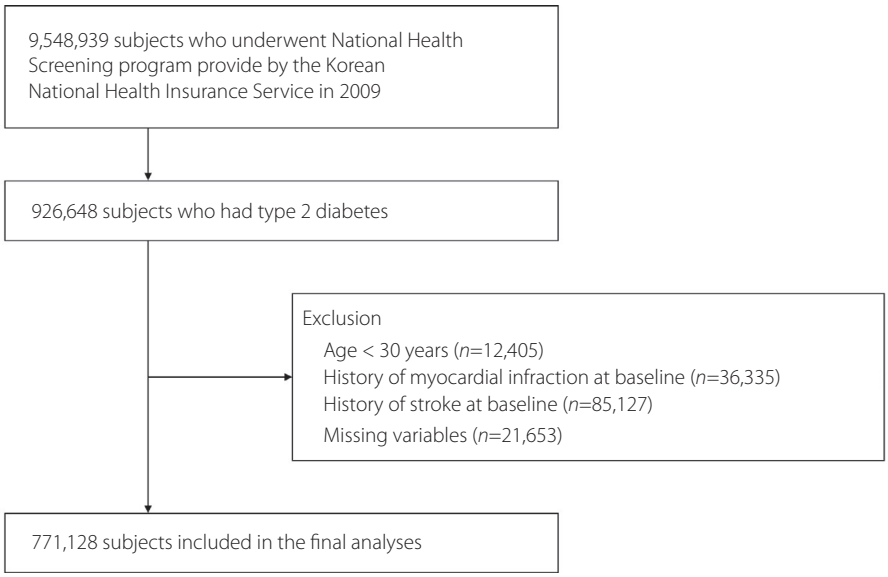

Figure 1 | Selection of study patients.

Statistical analysis

The baseline characteristics of the study participants were compared using ANOVA for continuous variables and χ^2-test for categorical variables. The incidence rate of study outcomes was calculated by dividing the number of events by 1,000 person-years. Cox proportional hazards regression models were used to examine the association between vision and hearing impairments, and the hazard ratios (HR) and 95% confidence intervals (CI) of study outcomes before and after adjusting for potential confounding factors. A fully-adjusted model included age, sex, income, hypertension, dyslipidemia, diabetic retinopathy, smoking, alcohol, regular exercise, BMI, insulin use, number of oral antidiabetic medication, fasting glucose level, diabetes duration, aspirin, warfarin and P2Y12 inhibitors. The Kaplan–Meier curves were used to calculate the incidence probability of MI, stroke and death, and log-rank tests were carried out to investigate the differences in the effect of vision/hearing impairments on cardiovascular outcomes and death. We also carried out subgroup analyses of age, sex and the presence of diabetic retinopathy.

We used SAS (version 9.4; SAS Institute, Cary, NC, USA) for all statistical analyses, with *P*-values <0.05 considered significant.

RESULTS

Baseline characteristics of the study population

A total of 771,128 patients were included in the study (Figure 1). Table 1 shows the baseline characteristics of the study population based on the combination of vision and hearing impairments. The proportion of current smokers and heavy drinkers were highest in the vision impairment(−)/hearing impairment(−) group. Total cholesterol, BMI and glucose were lower in the impairment groups. The proportions of insulin use and oral hypoglycemic medications were greater in those with vision and/or hearing impairments.

The incidence and risk of MI, stroke, and all-cause mortality significantly increased in those with vision and/or hearing impairments (Table 2 and Figure 2). The HRs of the vision impairment(+)/hearing impairment(+) group were 2.497 (95% CI 2.300–2.711) for MI, 2.921 (95% CI 2.742–3.112) for stroke and 4.556 (95% CI 4.393–4.725) for all-cause mortality when compared with those of the vision impairment(−)/hearing impairment(−) group. After adjusting for confounding factors, the adjusted HRs were 1.362 (95% CI 1.252–1.481), 1.286 (95% CI 1.198–1.381) and 1.591 (95% CI 1.532–1.651) for MI, stroke and all-cause mortality, respectively. The vision impairment(+)/-hearing impairment(−) group showed greater HRs compared with the vision impairment(−)/hearing impairment(+) group for all outcomes before and after adjusting for confounding variables.

Table 3 shows the comparison of the adjusted HRs (95% CIs) of study outcomes in subgroups. The association between vision/hearing impairments and risk of stroke and all-cause mortality was more prominent in the younger (<65 years) age group (*P* for interaction <0.0001 for both). A more detailed subgroup analysis after stratification into age decades also showed similar results (Table S3). The association between vision/hearing impairments and risk of MI was stronger in men (*P* for interaction <0.0001), whereas the association between vision/hearing impairments and risk of all-cause mortality was stronger in women (*P* for interaction <0.0001). The risk of MI, stroke and mortality was greater in those with

Table 1 | Baseline characteristics of the study population based on the combination of vision and hearing impairments

	Vision impairment (–) Hearing impairment (–)	Vision impairment (–) Hearing impairment (+)	Vision impairment (+) Hearing impairment (–)	Vision impairment (+) Hearing impairment (+)	
n	658,223	43,671	60,514	8,720	
Age (years)	55.39 ± 11.1	62.99 ± 10.26	64.49 ± 11.13	70.39 ± 9.23	<0.0001
Sex (male)	428,789 (65.14)	27,265 (62.43)	24,521 (40.52)	3,556 (40.78)	<0.0001
Smoking					<0.0001
Non	343,344 (52.16)	25,182 (57.66)	43,649 (72.13)	6,392 (73.3)	
Ex	125,268 (19.03)	8,804 (20.16)	7,355 (12.15)	1,142 (13.1)	
Current	189,611 (28.81)	9,685 (22.18)	9,510 (15.72)	1,186 (13.6)	
Alcohol drinking					<0.0001
No	349,081 (53.03)	26,604 (60.92)	44,114 (72.9)	6,672 (76.51)	
Mild	235,974 (35.85)	13,087 (29.97)	12,538 (20.72)	1,540 (17.66)	
Heavy	73,168 (11.12)	3,980 (9.11)	3,862 (6.38)	508 (5.83)	
Income (lowest quartile)	145,065 (22.04)	9,150 (20.95)	13,514 (22.33)	1,826 (20.94)	<0.0001
Regular exercise	147,817 (22.46)	9,865 (22.59)	11,302 (18.68)	1,432 (16.42)	<0.0001
Insulin	45,206 (6.87)	3,945 (9.03)	7,643 (12.63)	1,188 (13.62)	<0.0001
Diabetic retinopathy	50,839 (7.72)	4,110 (9.41)	8,397 (13.88)	1,067 (12.24)	<0.0001
No. oral hypoglycemic medications					<0.0001
0	290,452 (44.13)	15,790 (36.16)	20,157 (33.31)	2,803 (32.14)	
1	104,098 (15.82)	8,244 (18.88)	11,019 (18.21)	1,722 (19.75)	
2	166,015 (25.22)	12,345 (28.27)	17,237 (28.48)	2,467 (28.29)	
≥3	97,658 (14.84)	7,292 (16.7)	12,101 (20)	1,728 (19.82)	
Total cholesterol (mg/dL)	199.37 ± 48.33	195.29 ± 42.72	198.15 ± 47.41	194.98 ± 45.35	<0.0001
Body mass index (kg/m^2)	25.08 ± 3.29	24.65 ± 3.21	24.62 ± 3.46	24.1 ± 3.41	<0.0001
Fasting glucose (mg/dL)	148.19 ± 49.47	143.53 ± 47.36	146.07 ± 53.64	142.33 ± 51.87	<0.0001
Systolic BP (mmHg)	128.97 ± 15.68	129.12 ± 16.06	130.68 ± 16.83	130.03 ± 17.01	<0.0001
Diastolic BP (mmHg)	79.46 ± 10.22	78.03 ± 10.24	78.72 ± 10.47	77.32 ± 10.45	<0.0001
Diabetes duration, ≥5 years	197,269 (29.97)	16,206 (37.11)	25,156 (41.57)	3,763 (43.15)	<0.0001
Hypertension	366,367 (55.66)	27,683 (63.39)	41,198 (68.08)	6,207 (71.18)	<0.0001
Dyslipidemia	258,287 (39.24)	16,888 (38.67)	24,744 (40.89)	3,205 (36.76)	<0.0001
Aspirin	162,844 (24.74)	13,263 (30.37)	19,135 (31.62)	2,987 (34.26)	<0.0001
Warfarin	2,238 (0.34)	249 (0.57)	345 (0.57)	56 (0.64)	<0.0001
P2Y12 inhibitors	13,099 (1.99)	1,288 (2.95)	1,809 (2.99)	253 (2.9)	<0.0001

BP, blood pressure.

diabetic retinopathy compared with those without (*P* for interaction <0.0001, 0.017 and <0.0001, respectively).

DISCUSSION

In the present nationwide longitudinal study, vision impairment and hearing impairment were associated with increased risks of MI, stroke and all-cause mortality in patients with type 2 diabetes. Patients with both vision and hearing impairments had the highest risk for MI and mortality. Those with only vision impairment showed higher cardiovascular risk and mortality compared with those with only hearing impairment. The present findings suggest that vision and hearing impairments are independently and synergistically important risk factors for adverse cardiovascular events and mortality in patients with type 2 diabetes.

To the best of our knowledge, there are no previous studies on cardiovascular diseases and mortality in diabetes patients with vision and hearing impairments. There are some possible explanations underlying the association between vision and hearing impairments and adverse cardiovascular outcomes and mortality. Vision and hearing impairments might reflect vascular health[17]. Vision impairment in patients with diabetes is largely associated with diabetic retinopathy[10]. Diabetic retinopathy, one of the main causes of vision impairment, has been associated with high cardiovascular diseases and mortality in patients with diabetes[15–17,19], Rajala *et al.*[17] reported higher cardiovascular disease mortality in patients with vision impairment due to diabetic retinopathy. Juutilainen *et al.*[15] also reported that proliferative diabetic retinopathy was an independent risk factor for cardiovascular mortality in type 2 diabetes. Others reported that retinopathy predicts cardiovascular diseases in these patients, which suggests similar pathophysiology related to widespread vascular damage[16,19].

However, the present results cannot be explained only by diabetic retinopathy, because the risks of cardiovascular outcomes and mortality in patients with or without diabetic

Table 2 | Incidence and risk of myocardial infarction, stroke and death in patients with type 2 diabetes with or without vision and hearing impairments

Impairment		*n*	Event	Duration (person-years)	Rate	Model 1	Model 2	Model 3	Model 4	Model 5
Vision impairment	Hearing impairment		Myocardial infarction							
−	−	65,8223	20,653	587,6150.64	3.5147	1 (Ref.)	1 (Ref.)	1 (Ref.)	1 (Ref.)	1 (Ref.)
−	+	43,671	2,043	37,3617.24	5.4681	1.563 (1.493, 1.636)	1.123 (1.072, 1.176)	1.112 (1.062, 1.165)	1.118 (1.067, 1.171)	1.117 (1.066, 1.170)
+	−	60,514	3,422	506,519.9	6.7559	1.933 (1.864, 2.004)	1.366 (1.316, 1.418)	1.299 (1.251, 1.349)	1.325 (1.276, 1.376)	1.324 (1.275, 1.375)
+	+	8,720	582	67,519.97	8.6196	2.497 (2.300, 2.711)	1.413 (1.299, 1.536)	1.331 (1.224, 1.447)	1.358 (1.249, 1.477)	1.362 (1.252, 1.481)
			Stroke							
−	−	658,223	30,211	5,836,285.1	5.1764	1 (ref.)	1 (ref.)	1 (ref.)	1 (Ref.)	1 (Ref.)
−	+	43,671	3,277	368,551.29	8.8916	1.722 (1.661, 1.786)	1.110 (1.070, 1.151)	1.102 (1.062, 1.143)	1.135 (1.090, 1.182)	1.134 (1.089, 1.180)
+	−	60,514	5,750	497,279.08	11.5629	2.243 (2.181, 2.307)	1.361 (1.321, 1.401)	1.294 (1.256, 1.332)	1.320 (1.277, 1.364)	1.318 (1.276, 1.362)
+	+	8,720	991	66,135.65	14.9844	2.921 (2.742, 3.112)	1.308 (1.226, 1.395)	1.227 (1.151, 1.309)	1.284 (1.196, 1.379)	1.286 (1.198, 1.381)
			Death							
−	−	658,223	58,252	5,946,150.44	9.7966	1 (ref.)	1 (ref.)	1 (ref.)	1 (Ref.)	1 (Ref.)
−	+	43,671	7,685	379,999.07	20.2237	2.074 (2.025, 2.124)	1.174 (1.146, 1.203)	1.156 (1.128, 1.184)	1.165 (1.137, 1.193)	1.163 (1.135, 1.191)
+	−	60,514	13,323	516,651.25	25.7872	2.648 (2.599, 2.698)	1.496 (1.467, 1.525)	1.391 (1.363, 1.418)	1.42 (1.392, 1.448)	1.417 (1.39, 1.446)
+	+	8,720	3,038	69,294.4	43.8419	4.556 (4.393, 4.725)	1.712 (1.650, 1.778)	1.546 (1.489, 1.605)	1.590 (1.532, 1.651)	1.591 (1.532, 1.651)

Model 1: Crude model. Model 2: Adjusted for age, sex, income, hypertension, dyslipidemia and diabetic retinopathy. Model 3: Adjusted for age, sex, income, hypertension, dyslipidemia, diabetic retinopathy, smoking, drinking regular exercise, body mass index, insulin, number of oral hypoglycemia medications and fasting glucose. Model 4: Adjusted for age, sex, income, hypertension, dyslipidemia, diabetic retinopathy, smoking, drinking regular exercise, body mass index, insulin, number of oral hypoglycemia medications, fasting glucose and diabetes duration. Model 5: Adjusted for age, sex, income, hypertension, dyslipidemia, diabetic retinopathy, smoking, drinking regular exercise, body mass index, insulin, number of oral hypoglycemia medications, fasting glucose, diabetes duration, aspirin, warfarin and P2Y12 inhibitors.

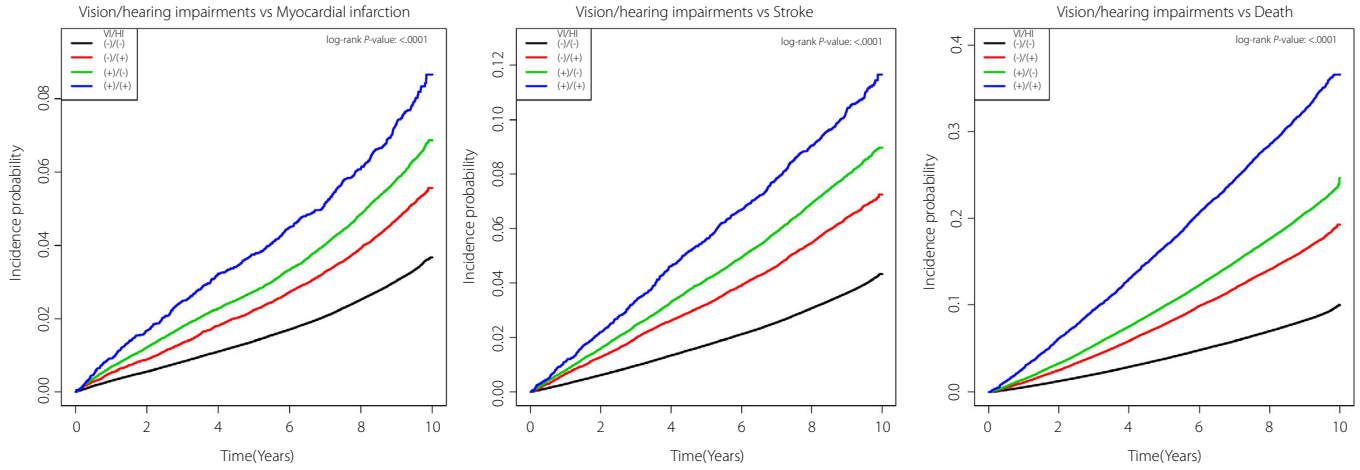

Figure 2 | Kaplan–Meier curves for the incidence probability of myocardial infarction, stroke and death according to vision/hearing impairments. HI, hearing impairment; VI, vision impairment.

retinopathy showed that vision impairment was still a risk factor for these adverse outcomes, even in patients without diabetic retinopathy. Siersma *et al.*[18] also found higher mortality in diabetes patients with vision impairment. In their study, diabetes patients with vision impairment were more likely to have cardiovascular disease, fractures, poor lifestyle behaviors, hypertension and peripheral neuropathy compared with diabetes patients with normal vision. In addition, we found that in patients with diabetic retinopathy, those with vision and hearing impairments had a lower HR for cardiovascular outcomes than those with only vision impairment. However, the HR for death was the highest in patients with vision and hearing impairments. The reason for this remains unclear and warrants further research.

Hearing loss is a less-established complication of diabetes, which might be caused by microvascular and neuropathic complications of the inner ear[9,12–14]. Hearing impairment was associated with albuminuria, a higher level of the albumin-to-creatinine ratio and a lower level of the estimated glomerular filtration rate in patients with diabetes in previous studies[24,25]. Although the risk of cardiovascular diseases and mortality with hearing loss has not been reported in patients with diabetes, hearing loss has been associated with increased cardiovascular diseases in the general population[26,27]. In a study by Sorrel *et al.*[27], sensorineural hearing loss was associated with a high stroke risk. The incidence of hearing loss was greater in those with greater cardiovascular risk factors[26].

Vision and hearing impairments might also have a negative impact on a person's ability to control diabetes and its complications: exercising, preparing healthy meals, taking insulin and medications, access to healthcare services, communicating with healthcare providers, and more[28,29]. In the present study, patients with vision or hearing impairments showed higher systolic BP, but lower total cholesterol, BMI, fasting glucose and diastolic BP, so the present results cannot be explained by diabetes control alone. The sensory deprivation might also lead to other morbidities, such as depression, cognitive decline, social isolation, falls, fractures and accidents, which in turn might contribute to the risk of cardiovascular diseases and death[29–31].

The use of objective measures of visual and hearing functions was a strength of the present study. In addition, the use of a nationwide longitudinal database, which includes almost all patients aged >40 years with diabetes, minimizes selection bias, resulting in more generalizability. Nevertheless, there were also limitations. First, because type 2 diabetes was defined based on ICD-10 codes or one measurement of fasting glucose level, the possibility of misclassification exists due to inclusion of other types of diabetes. Second, due to the characteristics of the database, information regarding the severity of diabetes or vision/hearing impairments was not included in the analyses. Although ICD-10 code or NDR was determined by a medical doctor, the severity of diseases could range widely. Also, the duration of vision/hearing impairments, which could affect cardiovascular outcomes and death, could not be accounted for. Furthermore, we did not take into consideration the causes of vision/hearing impairments. We attempted to mitigate this by subgroup analyses and multivariate analyses.

In conclusion, the present nationwide, population-based longitudinal study found that vision impairment and hearing impairment were independently associated with increased risks of MI, stroke and all-cause mortality in patients with type 2 diabetes. In addition, vision and hearing impairments synergistically increased the risk of MI and all-cause mortality, but not stroke. Furthermore, in patients aged <65 years, the HR of vision impairment was higher than those with vision and hearing impairments. The present findings suggest the importance of ophthalmologic and otologic care in patients with type 2 diabetes.

Table 3 | Subgroup analyses of risk of myocardial infarction, stroke and death in patients with type 2 diabetes with or without vision and hearing impairments

Subgroup	Impairment	*n*	Event	Duration	Rate	Model 5	*P* for interaction
			Myocardial infarction				
Age <65 years	Vision impairment (–) Hearing impairment (–)	511,178	12,419	4,635,813.49	2.6789	1 (Ref.)	0.394
	Vision impairment (–) Hearing impairment (+)	22,905	750	205,393.31	3.6515	1.160 (1.077, 1.250)	
	Vision impairment (+) Hearing impairment (–)	26,773	1,002	238,514.23	4.2010	1.396 (1.307, 1.490)	
	Vision impairment (+) Hearing impairment (+)	2,040	80	17,840.36	4.4842	1.308 (1.048, 1.632)	
Age ≥65 years	Vision impairment (–) Hearing impairment (–)	147,045	8,234	1,240,337.15	6.6385	1 (Ref.)	
	Vision impairment (–) Hearing impairment (+)	20,766	1,293	168,223.93	7.6862	1.084 (1.022, 1.151)	
	Vision impairment (+) Hearing impairment (–)	33,741	2,420	268,005.67	9.0297	1.253 (1.196, 1.313)	
	Vision impairment (+) Hearing impairment (+)	6,680	502	49,679.61	10.1047	1.304 (1.190, 1.429)	
			Stroke				
Age <65 years	Vision impairment (–) Hearing impairment (–)	511,178	15,747	4,620,166.12	3.4083	1 (Ref.)	<0.0001
	Vision impairment (–) Hearing impairment (+)	22,905	996	204,123.95	4.8794	1.162 (1.083, 1.247)	
	Vision impairment (+) Hearing impairment (–)	26,773	1,461	236,409.87	6.1799	1.519 (1.431, 1.612)	
	Vision impairment (+) Hearing impairment (+)	2,040	147	17,567.04	8.3679	1.656 (1.379, 1.987)	
Age ≥65 years	Vision impairment (–) Hearing impairment (–)	147,045	14,464	1,216,118.98	11.8936	1 (Ref.)	
	Vision impairment (–) Hearing impairment (+)	20,766	2,281	164,427.33	13.8724	1.111 (1.058, 1.167)	
	Vision impairment (+) Hearing impairment (–)	33,741	4,289	260,869.21	16.4412	1.257 (1.209, 1.307)	
	Vision impairment (+) Hearing impairment (+)	6,680	844	48,568.61	17.3775	1.259 (1.165, 1.361)	
			Death				
Age <65 years	Vision impairment (–) Hearing impairment (–)	511,178	25,941	4,680,512.6	5.5423	1 (Ref.)	<0.0001
	Vision impairment (–) Hearing impairment (+)	22,905	1,726	208,040.44	8.2965	1.162 (1.106, 1.221)	
	Vision impairment (+) Hearing impairment (–)	26,773	2,397	241,826.19	9.9121	1.606 (1.539, 1.676)	
	Vision impairment (+) Hearing impairment (+)	2,040	260	18,130.11	14.3408	1.891 (1.673, 2.138)	
Age ≥65 years	Vision impairment (–) Hearing impairment (–)	147,045	32,311	1,265,637.84	25.5294	1 (Ref.)	
	Vision impairment (–) Hearing impairment (+)	20,766	5,959	171,958.62	34.6537	1.149 (1.117, 1.181)	
	Vision impairment (+) Hearing impairment (–)	33,741	10,926	274,825.06	39.7562	1.332 (1.302, 1.362)	
	Vision impairment (+) Hearing impairment (+)	6,680	2,778	51,164.29	54.2957	1.478 (1.421, 1.538)	
			Myocardial infarction				
Male	Vision impairment (–) Hearing impairment (–)	428,789	13,712	3,795,709.12	3.6125	1 (Ref.)	<0.0001
	Vision impairment (–) Hearing impairment (+)	27,265	1,238	229,893.77	5.3851	1.077 (1.015, 1.143)	
	Vision impairment (+) Hearing impairment (–)	24,521	1,348	198,386.28	6.79482	1.276 (1.205, 1.352)	
	Vision impairment (+) Hearing impairment (+)	3,556	260	26,042.32	9.98375	1.472 (1.299, 1.669)	
Female	Vision impairment (–) Hearing impairment (–)	229,434	6,941	2,080,441.52	3.33631	1 (Ref.)	
	Vision impairment (–) Hearing impairment (+)	16,406	805	143,723.47	5.60103	1.193 (1.108, 1.285)	
	Vision impairment (+) Hearing impairment (–)	35,993	2,074	308,133.62	6.73085	1.335 (1.269, 1.404)	
	Vision impairment (+) Hearing impairment (+)	5,164	322	41,477.65	7.76322	1.243 (1.109, 1.392)	
			Stroke				
Male	Vision impairment (–) Hearing impairment (–)	428,789	19,335	3,773,255.33	5.1242	1 (Ref.)	0.8799
	Vision impairment (–) Hearing impairment (+)	27,265	2,077	226,393.27	9.1743	1.130 (1.074, 1.189)	
	Vision impairment (+) Hearing impairment (–)	24,521	2,350	194,971.01	12.0531	1.323 (1.260, 1.389)	
	Vision impairment (+) Hearing impairment (+)	3,556	402	25,544.03	15.7375	1.240 (1.112, 1.383)	

Table 3 (*Continued*)

Subgroup	Impairment	*n*	Event	Duration	Rate	Model 5	*P* for interaction
Female	Vision impairment (–) Hearing impairment (–)	229,434	10,876	2,063,029.77	5.2719	1 (Ref.)	
	Vision impairment (–) Hearing impairment (+)	16,406	1,200	142,158.02	8.4413	1.136 (1.062, 1.214)	
	Vision impairment (+) Hearing impairment (–)	35,993	3,400	302,308.08	11.2468	1.32 (1.263, 1.381)	
	Vision impairment (+) Hearing impairment (+)	5,164	589	40,591.62	14.5104	1.333 (1.213, 1.466)	
			Death				
Male	Vision impairment (–) Hearing impairment (–)	428,789	42,272	3,842,483.38	11.0012	1 (Ref.)	<0.0001
	Vision impairment (–) Hearing impairment (+)	27,265	5,420	233,591.52	23.2029	1.160 (1.127, 1.194)	
	Vision impairment (+) Hearing impairment (–)	24,521	6,570	202,265.44	32.4821	1.412 (1.375, 1.451)	
	Vision impairment (+) Hearing impairment (+)	3,556	1,496	26,776.84	55.8692	1.537 (1.458, 1.620)	
Female	Vision impairment (–) Hearing impairment (–)	229,434	15,980	2,103,667.05	7.5963	1 (Ref.)	
	Vision impairment (–) Hearing impairment (+)	16,406	2,265	146,407.55	15.4705	1.177 (1.126, 1.231)	
	Vision impairment (+) Hearing impairment (–)	35,993	6,753	314,385.81	21.4800	1.387 (1.347, 1.429)	
	Vision impairment (+) Hearing impairment (+)	5,164	1,542	42,517.56	36.2674	1.594 (1.511, 1.683)	
			Myocardial infarction				
No diabetic retinopathy	Vision impairment (–) Hearing impairment (–)	607,384	18,376	5,427,551.83	3.3857	1 (Ref.)	<0.0001
	Vision impairment (–) Hearing impairment (+)	39,561	1,795	338,672.14	5.3001	1.114 (1.060, 1.171)	
	Vision impairment (+) Hearing impairment (–)	52,117	2,740	437,467.71	6.2633	1.272 (1.220, 1.326)	
	Vision impairment (+) Hearing impairment (+)	7,653	495	59,149.27	8.3687	1.340 (1.223, 1.468)	
Diabetic retinopathy	Vision impairment (–) Hearing impairment (–)	50,839	2,277	448,598.81	5.0758	1 (Ref.)	
	Vision impairment (–) Hearing impairment (+)	4,110	248	34,945.1	7.0968	1.129 (0.988, 1.289)	
	Vision impairment (+) Hearing impairment (–)	8,397	682	69,052.19	9.8766	1.580 (1.447, 1.725)	
	Vision impairment (+) Hearing impairment (+)	1,067	87	8,370.7	10.3934	1.467 (1.182, 1.822)	
			Stroke				
No diabetic retinopathy	Vision impairment (–) Hearing impairment (–)	607,384	26,891	5,392,305.1	4.9869	1 (Ref.)	0.017
	Vision impairment (–) Hearing impairment (+)	39,561	2,884	334,279.32	8.6275	1.124 (1.076, 1.173)	
	Vision impairment (+) Hearing impairment (–)	52,117	4,751	429,553.69	11.0603	1.282 (1.236, 1.329)	
	Vision impairment (+) Hearing impairment (+)	7,653	853	57,865.55	14.7411	1.262 (1.168, 1.363)	
Diabetic retinopathy	Vision impairment (–) Hearing impairment (–)	50,839	3,320	443,979.99	7.4778	1 (Ref.)	
	Vision impairment (–) Hearing impairment (+)	4,110	393	34,271.96	11.4671	1.205 (1.075, 1.350)	
	Vision impairment (+) Hearing impairment (–)	8,397	999	67,725.39	14.7507	1.511 (1.396, 1.636)	
	Vision impairment (+) Hearing impairment (+)	1,067	138	8,270.1	16.6866	1.430 (1.184, 1.727)	
			Death				
No diabetic retinopathy	Vision impairment (–) Hearing impairment (–)	607,384	52,362	5,490,492.24	9.5368	1 (Ref.)	<0.0001
	Vision impairment (–) Hearing impairment (+)	39,561	6,916	344,268.98	20.0889	1.169 (1.140, 1.199)	
	Vision impairment (+) Hearing impairment (–)	52,117	11,256	445,559.61	25.2626	1.380 (1.351, 1.410)	
	Vision impairment (+) Hearing impairment (+)	7,653	2,684	60,606.61	44.2856	1.566 (1.504, 1.629)	
Diabetic retinopathy	Vision impairment (–) Hearing impairment (–)	50,839	5,890	455,658.2	12.9264	1 (Ref.)	
	Vision impairment (–) Hearing impairment (+)	4,110	769	35,730.09	21.5225	1.103 (1.022, 1.190)	
	Vision impairment (+) Hearing impairment (–)	8,397	2,067	71,091.64	29.0752	1.637 (1.555, 1.724)	
	Vision impairment (+) Hearing impairment (+)	1,067	354	8,687.79	40.7469	1.743 (1.564, 1.943)	

Model 5: Adjusted for age, sex, income, hypertension, dyslipidemia, diabetic retinopathy, smoking, drinking regular exercise, body mass index, insulin, number of oral hypoglycemia medications, fasting glucose, diabetes duration, aspirin, warfarin and P2Y12 inhibitors.

ACKNOWLEDGMENTS

National Health Information Database was provided by the National Health Insurance Service (NHIS) of Korea. The authors thank the National Health Insurance Service for cooperation. This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2019R1C1C1011528). The study sponsor was not involved in the design of the study; the collection, analysis and interpretation of data; writing the report; or the decision to submit the report for publication.

DISCLOSURE

The authors declare no conflict of interest.

Approval of the research protocol: This study was approved by the institutional review board of the Yeouido St. Mary's Hospital, Seoul, Korea.

Informed consent: Informed consent was waived, because we used publicly open and anonymized data.

Approval date of registry and the registration no. of the study/-trial: SC20ZESI0142, 6 November 2020.

Animal Studies: N/A.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1 | Visual disability classification.

Table S2 | Hearing disability classification.

Table S3 | Subgroup analyses of risk of myocardial infarction, stroke and death in patients with type 2 diabetes with or without vision and hearing impairments after stratification into age decades.