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Dementia in a Hearing-impaired Population According to Hearing Aid Use: A Nationwide Population-based Study in Korea

Hayoung Byun,[1] Jae Ho Chung,[1,2] Seung Hwan Lee,[1] Eun Mi Kim,[3] and Inah Kim[4]

Background: Hearing loss is considered a potentially modifiable risk factor for dementia. However, the effect of use of a hearing aid on the development of dementia has not been clearly established. We aimed to assess the incidence of dementia in hearing-impaired individuals according to hearing aid use in a nationwide population-based cohort study with matched controls.

Methods: This was a retrospective, longitudinal, cohort study of South Korean national claims data for individuals newly registered with hearing disabilities (better ear ≥40 dBHL with worse ear ≥80 dBHL, or better ear ≥60 dBHL) between 2004 and 2008. The hearing aid cohort comprised individuals who received hearing aid subsidies from the National Health Insurance within a year from disability registration. The comparison cohort comprised individuals without a record of a hearing aid claim during the study period after 1:1 matching for audiologic and sociodemographic factors with the hearing aid cohort. The occurrence of dementia was followed up until 2018.

Results: Each cohort comprised 8780 individuals. Overall incidence of dementia in the hearing aid and comparison cohorts were 156.0 and 184.5 per 10,000 person-years, respectively (incidence rate ratio = 0.85, 95% confidence interval 0.79–0.91). In a multivariable analysis of the whole study populations, hearing aid use (hazard ratio = 0.75, 95% confidence interval 0.70–0.81) attenuated the risk of dementia.

Conclusions: Dementia incidence in individuals with hearing disabilities was lower in hearing aid users than that in nonusers. Hearing rehabilitation with hearing aids should be encouraged for individuals with hearing loss.

Key words: Cognitive function, Dementia, Hearing aid, Hearing loss.

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INTRODUCTION

The global increase in life expectancy has resulted in population aging and therefore increased interest in age-related conditions such as hearing loss and dementia. Hearing loss is the third most prevalent health condition in the elderly, and about one-third of people older than 65 years have disabling hearing loss (Yueh et al. 2003). Adverse effects of hearing loss include social isolation, reduced daily activity, lower quality of life, and cognitive decline (Gopinath et al. 2012; Amieva & Ouvrard 2020). Hearing impairment has been suggested to be the most impactful modifiable risk factor for dementia in mid-life, with approximately 9% of dementia patients being linked to hearing loss (Livingston et al. 2020).

One of the greatest challenges in South Korea is its rapidly aging population. In 2021, the elderly population aged 65 or older accounted for about 16.5% of the total population. As the elderly population increases, the social impact of hearing loss and dementia also increases. The Korean government has reported that 7.2% of individuals over 65 had a hearing impairment in 2000 ("Statistics Korea. 2010 Census" 2011). About 10% of elderly individuals were living with dementia in 2018, and this proportion is expected to rise to 16% in 2050 (Ministry of Health and Welfare 2020; Shon & Yoon 2021).

In this era of the COVID-19 pandemic, the requirement to wear masks has made it even difficult for people with hearing loss to communicate by lipreading. Moreover, "social distancing" will likely exacerbate the effects of hearing loss on cognitive function by reducing social contact and increasing isolation. Although hearing loss has been reported consistently to be related to poor cognitive outcomes and incident dementia, there is still a paucity of studies that have investigated if hearing aids (HAs) can protect against cognitive decline and incident dementia (Amieva et al. 2015; Dawes et al. 2015a,b; Deal et al. 2015; Lin et al. 2011, 2013; Ray et al. 2018; Bucholc et al. 2020). A number of longitudinal studies have reported that hearing loss is independently associated with accelerated cognitive decline in older adults, and postulated that HAs could help prevent dementia (Amieva et al. 2015; Deal et al. 2015; Lin et al. 2011, 2013; Ray et al. 2018; Bucholc et al. 2020).

Previous findings were primarily focused on mild to moderate hearing loss. They used simple self-reports or one-time audiometric screening to define patients with hearing difficulties, and also lacked a method for evaluating the correct use of properly fitted HAs. To evaluate the effect of HA use, with a focus on people with moderate to severe hearing loss, we performed a nationwide retrospective cohort study of individuals registered as having a hearing disability who were eligible for HA subsidies and fitting tests in South Korea. The incidence of dementia was monitored for more than 10 years using claims data. The primary purpose of this study was to determine the incidence and risk of dementia in hearing-impaired people according to the use of HAs.

[1]Department of Otolaryngology-Head and Neck Surgery, College of Medicine, Hanyang University, Seoul, Republic of Korea; [2]Department of HY-KIST Bio-convergence, College of Medicine, Hanyang University, Seoul, Republic of Korea; [3]Department of Health Sciences, Hanyang University Graduate School, Seoul, Republic of Korea; and [4]Department of Occupational and Environmental Medicine, Hanyang University, Seoul, Republic of Korea.

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MATERIALS AND METHODS

Study Population

The National Health Insurance System (NHIS) of Korea has provided insurance for all Korean citizens since 1989. Information regarding use of medical services is maintained in the NHIS database and is available for research purposes with formal approval. We used National Health Information Database (NHIS-2019-1-414) data from January 2002 to 2018. The NHIS database classifies diseases according to the 10th revision of the International Statistical Classification of Diseases and Related Health Problems (ICD-10).

National registry data for persons with disabilities of the Korean Ministry of Health and Welfare are provided to the NHIS for welfare services. Individuals registered as having a hearing disability are eligible for social and financial assistance, including subsidies for hearing rehabilitation, discounts or exemptions from telecommunications and public transport fares, and tax reductions. The present study enrolled hearing-impaired people who satisfied the criteria for disability registration based on the NHIS database.

This investigation was approved by the local ethics review board (Hanyang University Guri Hospital Institutional Review Board, GURI 2019-04-010) and performed in accordance with the Declaration of Helsinki and good clinical practice guidelines.

Study Design

This study was a retrospective, longitudinal, cohort study. The cohort population comprised individuals newly registered as having a hearing disability during the 5-year index period from January 2004 to December 2008 (Fig. 1). Individuals diagnosed with dementia before the registration, those with multiple disabilities, and those under the age of 30 or over the age of 80 at the time of registration were excluded (Fig. 2). Among the enrolled hearing-impaired population, individuals with records of HA subsidies within a year from the time of hearing disability registration were assigned to the HA cohort. Those among the hearing-impaired population who did not have a record of a HA subsidy for the observation period from January 2004 to December 2018 were assigned to the comparison cohort (non-HA cohort), followed by 1:1 matching between the non-HA and HA cohort for age, sex, income, urbanization level, Charlson comorbidity index score, year of disability registration, and grade of hearing disability (Charlson et al. 1987). The occurrence of dementia was monitored in both the HA cohort and non-HA cohort until 2018. We use the STROBE statement to report our findings.

Hearing Levels of Individuals With Hearing Disabilities

To be registered as having a hearing disability in Korea, individuals with a documented history of at least 6 months of nonfluctuating hearing losses have to undergo three pure-tone audiometry and speech audiometry tests performed in qualified otolaryngology centers at intervals of 3–7 days, along with a relevant auditory brainstem response test. Test results and medical certificates are reviewed by two otolaryngologists affiliated with the National Pension Service to determine disability registration based on the severity of the hearing loss.

Hearing thresholds are calculated based on average pure-tone thresholds at four frequencies using the following formula: (0.5 kHz + 1 kHz + 1 kHz + 2 kHz + 2 kHz + 4 kHz)/6. Hearing disability in Korea was classified into five levels according to the calculated average pure-tone threshold: grade 2 (better ear ≥ 90 dB HL), grade 3 (better ear ≥ 80 dB HL), grade 4 (better ear ≥ 70 dB HL), grade 5 (better ear ≥ 60 dB HL), and grade 6 (worse ear ≥ 80 dB HL and better ear HL ≥ 40 dB HL). In the present study, individuals with grades 2 and 3 were considered to have "profound hearing impairment," while those with grades 4, 5, and 6 were classified as having "moderate to severe hearing impairment" with reference to the World Health Organization grades of hearing impairment (Olusanya et al. 2019).

HA Subsidies in Individuals With Hearing Disabilities

The National Pension Service of the Korean government has been providing HA subsidies for the hearing impaired once every 5 years since 1999; before 2015, hearing-impaired individuals received approximately $300 per one device, and since 2015, $1000 per device has been provided. When otolaryngologists issue a HA prescription to patients with a hearing disability, the patients purchase the HAs from distributors of their choice. Claims for HAs are paid to the sellers after an otolaryngologist checks the purchased device through direct inspection and aided audiometry and issues a confirmation document. In this

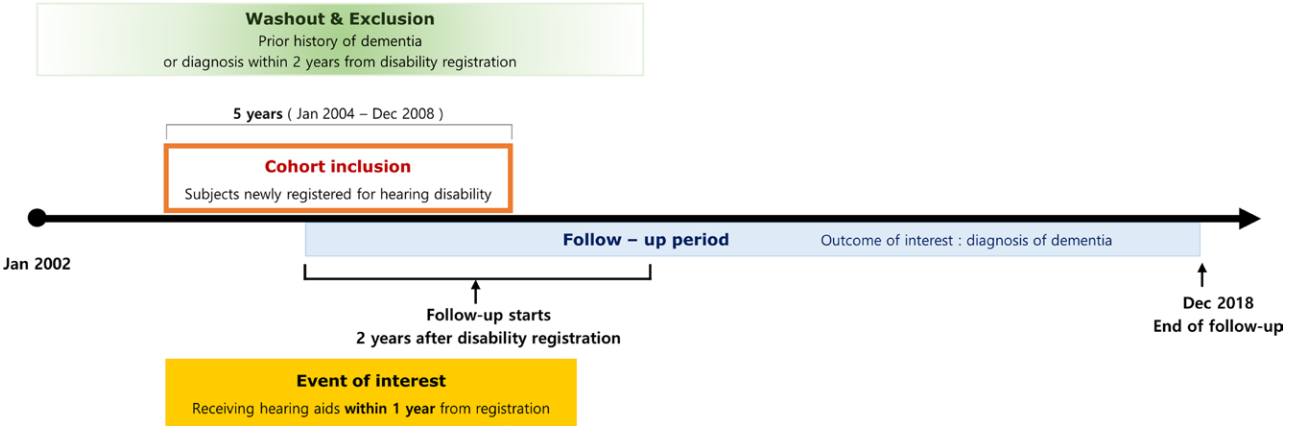

Fig. 1. Brief timeline of the cohort.

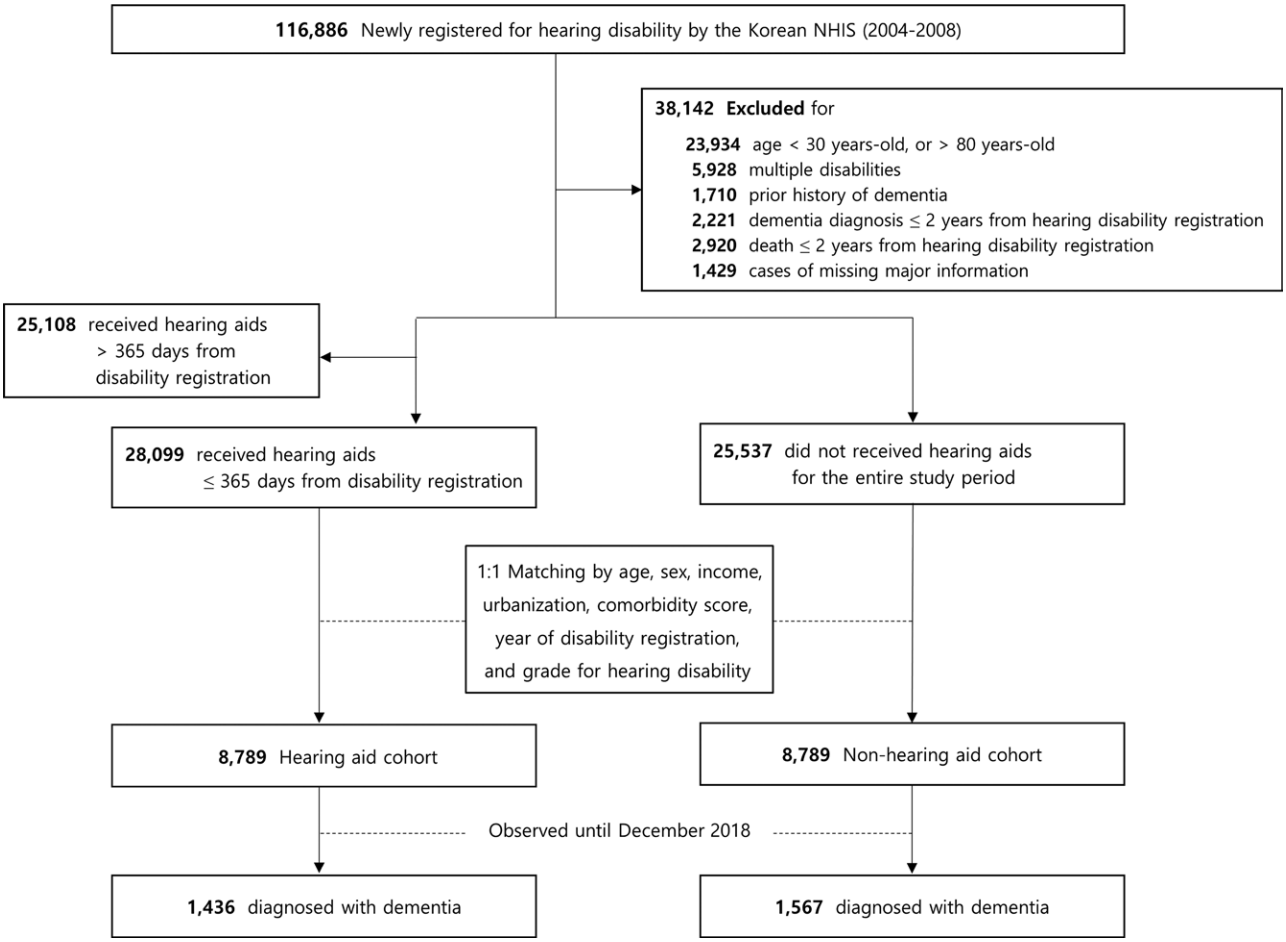

Fig. 2. Flow diagram of study cohort construction.

study, subjects who received a HA subsidy within 1 year from hearing disability registration were included in the HA cohort. And individuals who did not purchase HAs were assigned as non-HA cohort.

Operational Definition of Dementia

The diagnostic codes for dementia included Alzheimer's disease (ICD-10 codes F00 and G30), vascular dementia (F01), dementia in other diseases classified elsewhere (F02), unspecified dementia (F03), delirium superimposed on dementia (F051), and senile degeneration of the brain (G331). Exclusion was made for a previous history of dementia if any of the diagnostic codes were once identified during the washout period (Figs. 1 and 2). For the outcome of interest, dementia diagnosis was determined when three or more new related claims were identified.

Other Parameters Related to Dementia

Sociodemographic factors including age, sex, income, urbanization level, and comorbidities were assessed. Clinical factors previously shown to be associated with dementia were also evaluated, including ischemic heart disease (I21-25), cerebrovascular disease (G45-46, I60-69, H340), depression (F3), hypertension (I10-15), diabetes (E10-14, E11), head trauma (S01-09), and alcohol-related disorders (F10, G621, G312, G721, I426, K292, K852, K860, K700, K 701, K702, K703, K704, K709, Q860).(Livingston et al. 2020).

Statistical Analysis

Data were analyzed using SAS Enterprise Guide software version 7.1 (SAS Institute, Inc., Cary, NC). Simple Random Sampling was performed for 1:1 matching process. Demographic characteristics of the study population are summarized as percentages for categorical variables and means and standard deviations for continuous variables. Person-years were calculated by adding up all observation years per patient from the time of enrollment to the endpoint: dementia diagnosis, censor from death, or end of study period. Incidence rates (IRs) per 10,000 person-years were calculated with 95% confidence intervals (CIs). Ratios of IR (IRR) for dementia were calculated for the HA cohort relative to the non-HA group. After validation of the proportional hazards assumption using a Kaplan–Meyer survival curve estimates, a Cox proportional hazards regression model was used to analyze the risk of dementia in hearing loss individuals [hazard ratio (HR)] according to included covariates.

Data Availability

This study used the KNHIS database with permission. Data can be shared by request from any qualified investigator for purposes of replicating procedures and results.

RESULTS

Demographic Characteristics of the Study Population

A total of 116,886 individuals were registered as having a hearing disability during the index period from January 2004 to December 2008. After application of the exclusion criteria, a total of 28,099 patients that received HA subsidies within a year from registration were identified (Fig. 2). Through a 1:1 matching process, an HA cohort group and a non-HA cohort group, both comprising 8789 individuals, were established (Fig. 2; Table 1).

Mean age in both groups was 66.2 years and male subjects accounted for 62.3% of the total study population. The average follow-up period from enrollment to dementia diagnosis or the end of observation (December 2018) in the HA and non-HA cohorts was 10.5 and 9.7 years, respectively. The majority of individuals in both cohorts had moderate to severe hearing impairment (84.9%), while the remaining individuals in both groups had profound hearing impairment (Table 1).

Incidence of Dementia According to HA Use

In the HA cohort, 1436 of 8789 subjects were newly diagnosed with dementia during the observation period (IR 156.0 per 10,000 person-years, 95% CI 147.9 to 164.1), while 1567 subjects developed dementia in the non-HA cohort (IR 184.5 per 10,000 person-years, 95% CI 175.4 to 193.47) (Table 2).

The IR of dementia was higher in women than men: 205.2 versus 126.2 per 10,000 person-years in the HA cohort, and 279 versus 145 per 10,000 person-years in non-HA cohort, respectively (Table 2). In both females and males, the incidence of dementia was lower in the HA cohort than in the non-HA cohort (IRR 0.82, 95% CI 0.74 to 0.91 in women; IRR 0.87, 95% CI 0.79 to 0.96 in men). In subjects older than 65 years, incidence of dementia in the HA cohort was 0.81 times lower than that in the non-HA cohort (95% CI 0.75 to 0.88). In individuals with moderate to severe hearing impairment, the incidence of dementia in the HA cohort was 0.84 times lower than that in the non-HA cohort (95% CI 0.78 to 0.91).

The Kaplan–Meier analysis and log-rank test demonstrated that there was a significant difference in the development of dementia between the HA cohort and the non-HA cohort ($p < 0.001$, Fig. 3A). In addition, subgroup analysis showed that in both genders the HA users had lower cumulative rates of dementia than the non-HA users (Fig. 3B).

Risk Factors for Dementia in Subjects With Hearing Loss

In multivariable analysis of the whole cohort population, statistically meaningful protective factors were HA use (adjusted HR = 0.75, 95% CI 0.70 to 0.81) and above-median income (adjusted HR = 0.87, CI 0.78 to 0.97) (Fig. 4).

In a subgroup analysis, overall factors were similar between group, diabetes, and head trauma were associated with dementia risk in the HA cohort, while female living in a rural area and low income increased the risk of dementia in the non-HA cohort (see Table in Supplemental Digital Content 1, http://links.lww.com/EANDH/B22, which illustrates the HR for the development of dementia in each cohort).

DISCUSSION

This study evaluated the effect of HA use on the incidence of dementia in a hearing-impaired population using national disability registry and claims data in South Korea. During the 10-year average follow-up period, individuals who received HAs had a 0.85 times lower incidence of dementia than sociodemographically matched hearing-impaired people who never used HAs. The adjusted HR of HA use for dementia development in individuals with hearing disabilities was 0.75 (95% CI 0.70 to 0.81). This result suggests that HA use is an independent attenuating factor for incident dementia in people with moderate to severe hearing loss.

The association between hearing loss and cognitive decline in older adults is an emerging concern, as a number of studies have reported that untreated hearing loss is negatively associated with cognitive function (Lin 2011, 2013; Amieva et al. 2015; Deal et al. 2015; Ray et al. 2018). An important question to be answered is whether hearing rehabilitation can attenuate declines in cognitive function. Due to ethical issues with intervention trials to assess this issue, observational studies have been the main type of study performed to determine whether HA use reduces the risks of cognitive decline and dementia. In a study derived from the Health, Aging and Body Composition study, 1984 older adults aged 74 to 83 years were followed up for 6 years; HA use was not significantly associated with lower risk for incident cognitive impairment in this study (Lin et al. 2013). However, the average pure-tone threshold of hearing loss was 38.7 dB HL and HA use was assessed by questionnaire (Lin et al. 2013). By contrast, a pilot study within the Atherosclerosis Risk in Communities Neurocognitive Study reported that estimated cognitive decline over 13 years in 253 participants with hearing impairments was greatest in those individuals who did not wear HAs (Deal et al. 2015). In that study, however, nonusers had more comorbidities at a younger age, and there may have been socioeconomic and educational differences between HA users and nonusers (Deal et al. 2015). A longitudinal study of 2114 individuals conducted using data from the National Alzheimer's Coordinating Center in the United States reported that HAs users were at significantly lower risk of developing all-cause dementia compared to nonusers (Bucholc et al. 2020). In our study, we assessed the incidence of dementia in a nationwide hearing-impaired population with defined hearing levels and verified HAs at the time of inclusion. In addition, socioeconomic status, dwelling area, and other dementia-related comorbidities were included in our analysis. To date, this is the first longitudinal report of a nationwide cohort of individuals with hearing disabilities to examine the effect of HA use along with other risk factors on the incidence of dementia. Analysis of matched HA user and nonuser groups revealed that HA users had a significantly lower incidence of dementia than nonusers. We also assessed adjusted HRs for included comorbidities in the combined and individual cohorts; see Fig. 4 (and Table in Supplemental Digital Content 1, http://links.lww.com/EANDH/B22) and found that factors associated with socioeconomic status (urbanization level and income) were associated with dementia risk in the non-HA cohort.

In terms of hearing level, a positive association between the severity of hearing loss and dementia risk had been suggested such that individuals with mild to severe hearing loss having a 2- to 5-fold increased risk of incidence of all-cause dementia compared to those with normal hearing (Lin, Metter, et al. 2011). In that study, dementia developed in 16.8% (21/125) of individuals with mild hearing loss (25 to 40 dB), 28.3% (15/53) of those with moderate hearing loss (41 to 70 dB) and 33.3%

TABLE 1. Baseline characteristics of the study cohort

	HA Cohort		Non-HA Cohort	
	N = 8789	(%)	N = 8789	(%)
Gender				
Male	5473	(62.3)	5473	(62.3)
Female	3316	(37.7)	3316	(37.7)
Age (mean ± SD, yrs)	66.2 ± 9.8		66.2 ± 9.8	
<65	3154	(35.9)	3154	(35.9)
≥65	5635	(64.1)	5635	(64.1)
Follow-up years*	10.5		9.7	
Income (quartiles)				
Lowest	1899	(21.6)	1899	(21.6)
Lower mid	1670	(19.0)	1670	(19.0)
Upper mid	1923	(21.9)	1923	(21.9)
Highest	3297	(37.5)	3297	(37.5)
Urbanization level				
Metropolis	3972	(45.2)	3972	(45.2)
Urban	3811	(43.4)	3811	(43.4)
Rural	1006	(11.4)	1006	(11.4)
Hearing disability (Korean grade)				
2 (better ear ≥ 90 dB HL)	321	(3.7)	321	(3.7)
3 (better ear ≥ 80 dB HL)	1003	(11.4)	1003	(11.4)
4 (better ear ≥ 70 dB HL)	2403	(27.3)	2403	(27.3)
5 (better ear ≥ 60 dB HL)	3583	(40.8)	3583	(40.8)
6 (worse ear ≥ 80 dB HL and better ear HL ≥ 40 dB HL)	1479	(16.8)	1479	(16.8)
Severity of hearing Loss (WHO grade)† [b]				
Moderate to severe	7465	(84.9)	7465	(84.9)
Profound	1324	(15.1)	1324	(15.1)
Charlson Comorbidity Index				
0	5395	(61.4)	5395	(61.4)
1	2229	(25.4)	2229	(25.4)
2	695	(7.9)	695	(7.9)
≥3	470	(5.3)	470	(5.3)
Comorbidity				
Ischemic heart disease	1067	(12.1)	1122	(12.8)
Cerebrovascular disease	1107	(12.6)	1066	(12.1)
Depression	590	(6.7)	666	(7.6)
Hypertension	3998	(45.5)	4105	(46.7)
Diabetes	1687	(19.2)	1730	(19.7)
Head trauma	662	(7.5)	698	(7.9)
Alcohol-related diseases	327	(3.7)	323	(3.7)
Death during follow-up period	2479	(28.2)	3448	(39.2)
Before dementia diagnosis	1816	(20.7)	2590	(29.5)
After dementia diagnosis	663	(7.5)	858	(9.8)
Diagnosis of dementia	1436	(16.3)	1567	(17.8)

Profound hearing impairment includes hearing disability grades 2 and 3.
**Average period from enrollment to dementia diagnosis or the end of observation.*
†Moderate to severe hearing impairment includes hearing disability grades 4, 5, and 6.
HA indicates hearing aid.

(2/6) of those with severe hearing loss (>70 dB) (Lin, Metter, et al. 2011). In our study, hearing-impaired individuals were divided into two groups: moderate to severe (<80 dB) and profound hearing loss (≥80 dB). Although the result also showed a higher risk of dementia in the latter, the CI did not support statistical significance (Table 2; Fig. 4). This may have been because of the relatively small number of individuals with profound hearing loss (1324/8789, 15.1%), or because the hearing rehabilitation achieved by HAs in the case of profound hearing loss is not as pronounced as in milder hearing loss.

Several hypotheses to explain the association between hearing loss and dementia have been proposed. First, the common cause theory suggests that multiple sensory and cognitive systems decline in parallel and share a common underlying pathology of the aging process (Wayne & Johnsrude 2015). The role of HAs on cognitive function from this perspective is limited. The cognitive load hypothesis theorizes that individuals with hearing impairments need greater cognitive resources for auditory processing, and that effortful listening can have detrimental associations with other cognitive processes (Tun et al. 2009; Martini et al. 2014; Wayne & Johnsrude 2015). Therefore, a causal relationship is expected between peripheral hearing loss and corresponding cognitive decline (Tun et al. 2009; Martini et al. 2014; Wayne & Johnsrude 2015). The cascade hypothesis supports a causal interaction between hearing loss and cognitive decline based on the fact that peripheral hearing loss induces secondary changes in brain structures and leads to social isolation via withdrawal from social contacts (Cacioppo & Hawkley 2009; Eckert et al. 2012). Reduced social-stimulatory input could lead to a reduction in general cognitive function (Lin

TABLE 2. IR and IRR of dementia in the study cohort

	HA Claims (n = 8789)					No HA Claims (n=8,789)						
	N	Dementia	Person-Year	IR	95% CI	N	Dementia	Person-Year	IR	95% CI	IRR	95% CI
Overall	8789	1436	92,061	156.0	(147.9–164.1)	8789	1567	84,918	184.5	(175.4–193.7)	0.85	(0.79–0.91)
Gender												
Male	5473	724	57,362	126.2	(117.0–135.4)	5473	765	52,714	145	(134.8–155.4)	0.87	(0.79–0.96)
Female	3316	712	34,699	205.2	(190.1–220.3)	3316	802	32,204	249	(231.8–266.3)	0.82	(0.74–0.91)
Age (yrs)												
<65	3154	139	36,558	34.1	(28.2–40.0)	3154	128	37,514	38	(31.7–44.3)	0.9	(0.71–1.14)
≥65	5635	1428	48,360	239.8	(226.8–252.8)	5635	1308	54,547	298.3	(280.0–310.6)	0.81	(0.75–0.88)
Grade of hearing level*												
Moderate to severe	7465	1190	78,265	152	(143.4–160.7)	7465	1306	72,239	180.8	(171.0–190.6)	0.84	(0.78–0.91)
Profound	1324	246	13,796	178.3	(156.0–200.6)	1324	261	12,679	205.8	(180.9–230.8)	0.87	(0.73–1.03)

Severe hearing loss, average pure-tone thresholds.
Profound hearing loss, average pure-tone thresholds.
**Moderate to severe hearing impairment includes hearing disability of the better ear < 80 dB HL (grades 4 and 5) or worse ear ≥ 80 dB HL with better ear ≥ 40 dB HL (grade 6); profound hearing impairment includes hearing disability of better ear ≥ 80 dB HL (grades 2 and3).*
CI indicates confidence interval; IR, incidence rate (per 10,000 person-years); IRR, incidence rate ratio.

2012). Use of a HA could help to alleviate cognitive overload, as well as maintain social engagements and prevent secondary degenerative changes in the central auditory system caused by peripheral hearing deprivation (Qiu & Fratiglioni 2018). Another interesting additional hypothesis is overdiagnosis of dementia in individuals with hearing loss (Hill-Briggs et al. 2007; Uchida et al. 2019). Given that several cognitive function tests require auditory capability, hearing loss possibly exaggerates the severity of cognitive impairment measured by these tests. HAs could therefore potentially help prevent overdiagnosis of dementia in individuals with hearing loss. Our findings concerning HA use and dementia support the theories of cognitive load, cascade, and overdiagnosis.

This study has several limitations. First, factors not included in the NHIS database such as education level, detailed cognitive function, smoking, physical activity, and body weight could not be analyzed. We therefore evaluated new cases of dementia among people with hearing impairment without a prior history of dementia-related conditions. In an effort to overcome the limitation, a through 1:1 matching process was conducted for known socioeconomic factors including income and urbanization level. Second, although HAs and initial fitting were validated by otolaryngologists to confirm the benefit of HAs, a certain portion of people may not have used their HAs regularly. According to a report based on the Korea National Health and Nutrition Examination surveys (2010 to 2012), about 73.4% of participants who had HAs reported regular use of them (Moon et al. 2015). Considering that the main reason for not using HAs in hearing disabilities were that they choose not to have HAs (Ministry of Health and Welfare 2017), the usage rate was expected to be maintained once they started wearing HAs. In the present study, even if the usage rate of HAs in the HA cohort was lower than reported in previous studies, it is unlikely to fundamentally affect the results, as this factor would only attenuate the effect of HA use. Third, an interesting point to consider is that not only the effect of the HAs themselves but also the characteristics of people who use HAs could have affected the outcomes. Possible traits of HA users may include

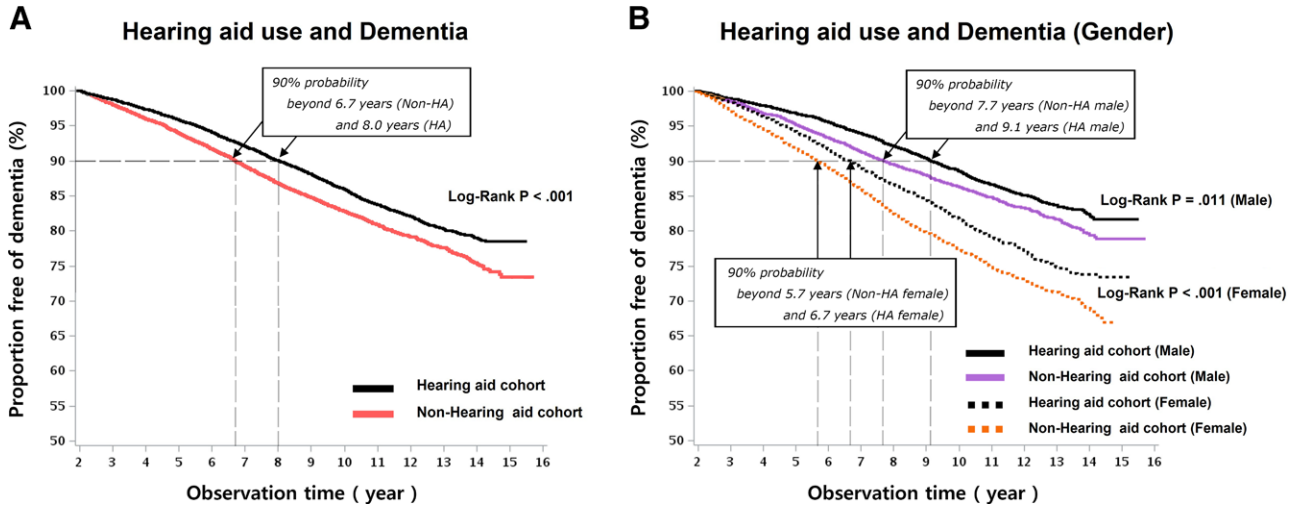

Fig. 3. The Kaplan–Meier survival analysis for incidence of dementia according to hearing aid use. The HA cohort had a lower cumulative rate of dementia than the non-HA cohort (A). Females had a higher cumulative rate of dementia than males. Subgroup analysis showed that both genders of the HA cohort had a lower cumulative rate of dementia than the those of the non-HA cohort (B). Estimated follow-up years with 90% probability free of dementia were indicated (square boxes). HA indicates hearing aid.

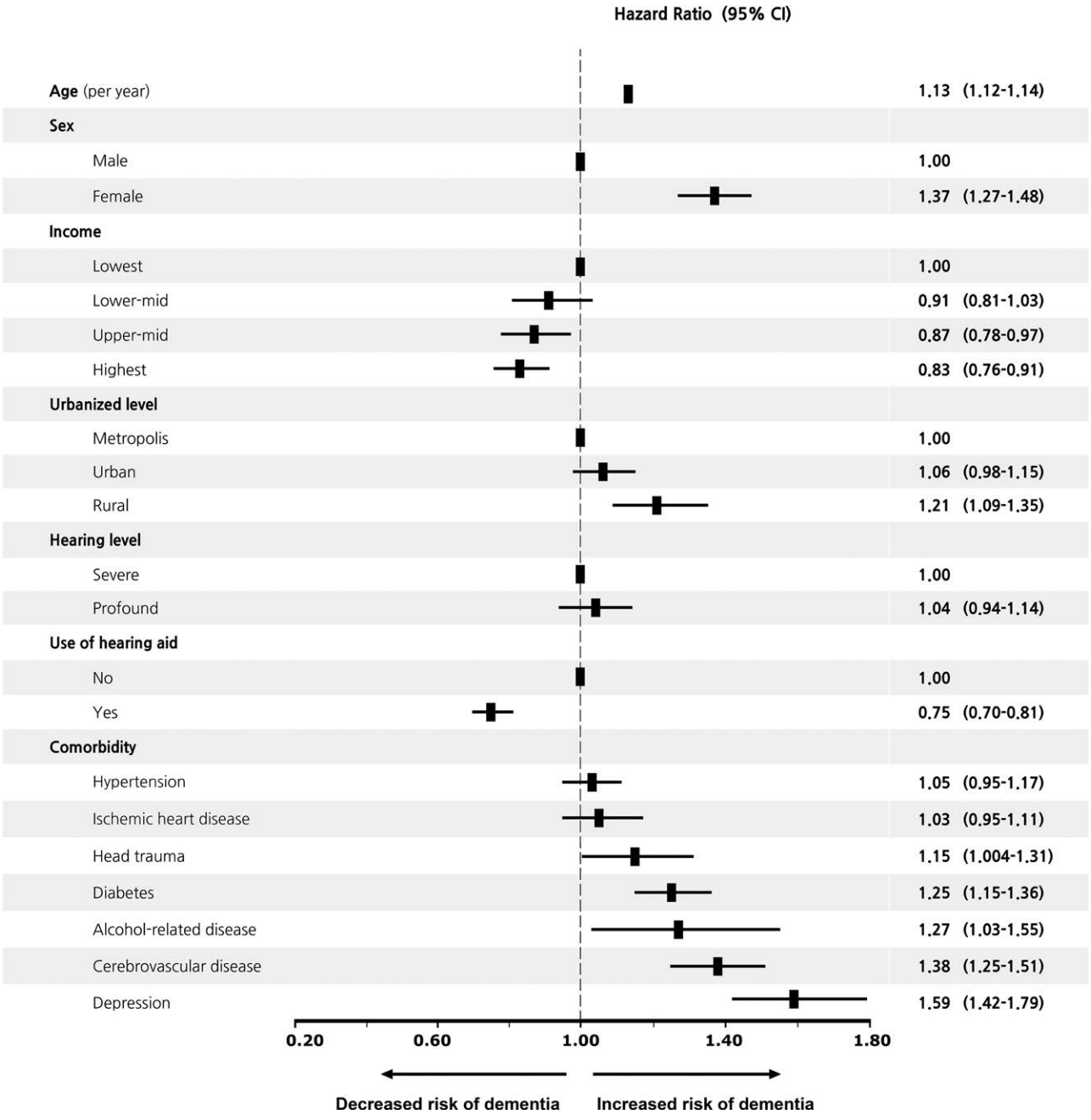

Fig. 4. Hazard ratios for the development of dementia.

better family support, a personality free from HA stigma, and a willingness to lead a healthy social life and engage in society. Finally, both hearing loss and dementia are chronic condition rather than acute episode, and it would take time for the HAs to work for cognitive function. To reduce biases from this issue, we excluded the subjects who developed dementia within 2 years from hearing disability registration to give time for HA adaptation. Despite those limitations, the present study could provide the value of HA use against dementia development based on nationwide population data. Well-designed prospective studies with ethically appropriate interventions should be performed in the future to gain a more comprehensive understanding of the effects of hearing loss and rehabilitation on cognitive decline.

CONCLUSIONS

This study showed that dementia incidence among individuals with hearing disabilities was lower in HA users than nonusers. People with hearing disabilities should be provided with sufficient information and encouraged to participate in hearing rehabilitation.

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Address for correspondence: Jae Ho Chung, Department of Otolaryngology-Head and Neck Surgery, Department of HY-KIST Bio-convergence, College of Medicine, Hanyang University, 222-Wangshimni-ro, Seongdong-gu, Seoul 04763, Republic of Korea. E-mail: jaeho.chung.md@gmail.com

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REFERENCES

Amieva, H., & Ouvrard, C. (2020). Does treating hearing loss in older adults improve cognitive outcomes? A review. *J Clin Med*, *9*, E805.

Amieva, H., Ouvrard, C., Giulioli, C., Meillon, C., Rullier, L., Dartigues, J. F. (2015). Self-reported hearing loss, hearing aids, and cognitive decline in elderly adults: A 25-year study. *J Am Geriatr Soc*, *63*, 2099–2104.

Bucholc, M., McClean, P. L., Bauermeister, S., Todd S., Ding X., Ye Q., Wang D., Huang W., Maguire L. P. (2020). Association of the use of hearing aids with the conversion from mild cognitive impairment to dementia and progression of dementia: A longitudinal retrospective study. *Alzheimers Dement (N Y), 7*, e12122.

Cacioppo, J. T., & Hawkley, L. C. (2009). Perceived social isolation and cognition. *Trends Cogn Sci*, *13*, 447–454.

Charlson, M. E., Pompei, P., Ales, K. L., MacKenzie, C. R. (1987). A new method of classifying prognostic comorbidity in longitudinal studies: Development and validation. *J Chronic Dis*, *40*, 373–383.

Dawes, P., Cruickshanks, K. J., Fischer, M. E., Klein, B. E., Klein, R., Nondahl, D. M. (2015a). Hearing-aid use and long-term health outcomes: Hearing handicap, mental health, social engagement, cognitive function, physical health, and mortality. *Int J Audiol*, *54*, 838–844.

Dawes, P., Emsley, R., Cruickshanks, K. J., Moore, D. R., Fortnum, H., Edmondson-Jones, M., McCormack, A., Munro, K. J. (2015b). Hearing loss and cognition: The role of hearing AIDS, social isolation and depression. *PLoS One*, *10*, e0119616.

Deal, J. A., Sharrett, A. R., Albert, M. S., Coresh, J., Mosley, T. H., Knopman, D., Wruck, L. M., Lin, F. R. (2015). Hearing impairment and cognitive decline: A pilot study conducted within the atherosclerosis risk in communities neurocognitive study. *Am J Epidemiol*, *181*, 680–690.

Eckert, M. A., Cute, S. L., Vaden, K. I. Jr, Kuchinsky, S. E., Dubno, J. R. (2012). Auditory cortex signs of age-related hearing loss. *J Assoc Res Otolaryngol*, *13*, 703–713.

Gopinath, B., Schneider, J., McMahon, C. M., Teber, E., Leeder, S. R., Mitchell, P. (2012). Severity of age-related hearing loss is associated with impaired activities of daily living. *Age Ageing*, *41*, 195–200.

Hill-Briggs, F., Dial, J. G., Morere, D. A., Joyce, A. (2007). Neuropsychological assessment of persons with physical disability, visual impairment or blindness, and hearing impairment or deafness. *Arch Clin Neuropsychol*, *22*, 389–404.

Lin, F. R. (2011). Hearing loss and cognition among older adults in the United States. *J Gerontol A Biol Sci Med Sci*, *66*, 1131–1136.

Lin, F. R. (2012). Hearing loss in older adults: Who's listening? *JAMA*, *307*, 1147–1148.

Lin, F. R., Ferrucci, L., Metter, E. J., An, Y., Zonderman, A. B., Resnick, S. M. (2011). Hearing loss and cognition in the Baltimore Longitudinal Study of Aging. *Neuropsychology*, *25*, 763–770.

Lin, F. R., Metter, E. J., O'Brien, R. J., et al. (2011). Hearing loss and incident dementia. *Arch Neurol*, *68*, 214–220.

Lin, F. R., Yaffe, K., Xia, J., Xue, Q. L., Harris, T. B., Purchase-Helzner, E., Satterfield, S., Ayonayon, H. N., Ferrucci, L., Simonsick, E. M.; Health ABC Study Group. (2013). Hearing loss and cognitive decline in older adults. *JAMA Intern Med*, *173*, 293–299.

Livingston, G., Huntley, J., Sommerlad, A., Ames, D., Ballard, C., Banerjee, S., Brayne, C., Burns, A., Cohen-Mansfield, J., Cooper, C., Costafreda, S. G., Dias, A., Fox, N., Gitlin, L. N., Howard, R., Kales, H. C., Kivimäki, M., Larson, E. B., Ogunniyi, A., Orgeta, V., et al. (2020). Dementia prevention, intervention, and care: 2020 report of the Lancet Commission. *Lancet*, *396*, 413–446.

Martini, A., Castiglione, A., Bovo, R., Vallesi, A., Gabelli, C. (2014). Aging, cognitive load, dementia and hearing loss. *Audiol Neurootol*, *19*(Suppl 1), 2–5.

Moon, I. J., Baek, S. Y., Cho, Y. S. (2015). Hearing aid use and associated factors in South Korea. *Medicine (Baltimore)*, *94*, e1580.

Ministry of Health and Welfare. National survey of the disabled persons. (2017). The 4th national dementia plan (2020) Studied and reported by: Ministry of Health and Welfare. Sejong city; South Korea.

Ministry of Health and Welfare. The 4th national dementia plan. (2020).

Olusanya, B. O., Davis, A. C., Hoffman, H. J. (2019). Hearing loss grades and the International classification of functioning, disability and health. *Bull World Health Organ*, *97*, 725–728.

Qiu, C., & Fratiglioni, L. (2018). Aging without dementia is achievable: Current evidence from epidemiological research. *J Alzheimers Dis*, *62*, 933–942.

Ray, J., Popli, G., Fell, G. (2018). Association of cognition and age-related hearing impairment in the english longitudinal study of ageing. *JAMA Otolaryngol Head Neck Surg*, *144*, 876–882.

Shon, C., & Yoon, H. (2021). Health-economic burden of dementia in South Korea. *BMC Geriatr*, *21*, 549.

Statistics Korea. 2010 Census (2011). http://www.kostat.go.kr.

Tun, P. A., McCoy, S., Wingfield, A. (2009). Aging, hearing acuity, and the attentional costs of effortful listening. *Psychol Aging*, *24*, 761–766.

Uchida, Y., Sugiura, S., Nishita, Y., Saji, N., Sone, M., Ueda, H. (2019). Age-related hearing loss and cognitive decline—The potential mechanisms linking the two. *Auris Nasus Larynx*, *46*, 1–9.

Wayne, R. V., & Johnsrude, I. S. (2015). A review of causal mechanisms underlying the link between age-related hearing loss and cognitive decline. *Ageing Res Rev*, *23*(Pt B), 154–166.

Yueh, B., Shapiro, N., MacLean, C. H., Shekelle, P. G. (2003). Screening and management of adult hearing loss in primary care: Scientific review. *JAMA*, *289*, 1976–1985.