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Research

Development of a case definition for hearing loss in community-based older adults: a cross-sectional validation study

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Abstract

Background: Research based in primary care suggests that hearing loss may be underreported as well as inconsistently recorded in patient histories. In this study, we aimed to develop and validate a case definition for hearing loss among older adults in primary care, using electronic medical records.

Methods: We used data from adult patients aged 55 years and older from 13 practices in the Southern Alberta Primary Care Research Network database, part of the Canadian Primary Care Sentinel Surveillance Network (CPCSSN), from Dec. 1, 2014, to Dec. 31, 2016. We developed a hearing loss case definition that was translated into an electronic algorithm. A record review was undertaken as the reference standard, followed by application of the algorithm to the sample. Validation metrics included sensitivity, specificity, positive predictive value and negative predictive value, as well as prevalence. We assessed risk factors using the Fisher exact test and odds ratios.

Results: The sample included 1000 patients; 496 (49.6%) were female and the mean age was 67.5 (standard deviation 9.6) years. Sensitivity of the case definition algorithm was determined to be 87.3% (95% confidence interval [CI] 76.5%–94.4%) with specificity valued at 94.8% (95% CI 93.1%–96.1%). Positive and negative predictive values were 52.9% (95% CI 42.8%–62.8%) and 99.1% (95% CI 98.2%–99.6%), respectively. The prevalence of hearing loss within the sample was 6.3% (95% CI 4.9%–7.9%). Older age was a significant risk factor for hearing loss (t = 4.98, 95% CI 3.76–8.65). Men had greater odds of hearing loss than women (odds ratio 1.65, 95% CI 0.98–2.79).

Interpretation: The validated case definition for hearing loss in community-based older adults had high sensitivity and specificity. It may be applied to surveillance and future epidemiologic research within the CPCSSN database.

Hearing loss is a common chronic condition among older adults. Feder and colleagues state that 65% of Canadian adults aged 70–79 experience hearing loss, and adults between the ages of 60 and 79 have a prevalence of 47%.[1] However, screening for hearing loss may not be common practice in primary care.[2] One study reported that 86% of older patients were not assessed for hearing loss without a patient request.[3] Similarly, another survey determined that 40% of family physician respondents did not routinely evaluate patients for hearing loss.[4] The 2012/2013 Canadian Health Measures Survey found that 77% of respondents found to have hearing loss had not received a diagnosis from a health care provider.[1] Furthermore, another study found that many physicians do not document hearing loss in electronic medical records (EMRs).[5]

In 2015, the US Armed Forces Health Surveillance Center published a case definition for noise-induced hearing loss,[6] composed of diagnostic billing codes from the *International Classification of Diseases, Ninth Revision* (ICD-9). The American Speech-Language-Hearing Association has also published a list of relevant ICD-9 codes for diagnosis of various types of hearing loss.[7] In this study, we aimed to validate a proposed case definition within the primary care context using EMR-derived data and to determine the burden of hearing loss in older adults in this patient population.

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Methods

Study design

This cross-sectional study to develop and validate a case definition for hearing loss in community-based older adults is based on the methodology of Williamson and colleagues (2014).[8] In this methodology, a case definition is developed and applied to Canadian Primary Care Sentinel Surveillance Network (CPCSSN) data[9] in the form of an electronic algorithm. A reference standard is created by means of a masked patient chart review to test the performance of the algorithm. Trained reviewers appraise each chart for evidence that the attending physician diagnosed the patient with the condition in question. Each patient's record is taken as a set of encounters. The reference standard is subsequently compared with the algorithm output and the outcome described using validation metrics. The method deems case definition algorithms to be of sufficient "validity" when they achieve a minimum of 70% sensitivity and specificity.[8]

In 2017, Williamson and colleagues refined this methodology when they replicated their initial study using CPCSSN records as a data source.[10] In the 2014 study,[8] the researchers gained remote access to the clinics' EMRs; in the 2017 study,[10] Williamson and colleagues validated the same set of case definitions developed in the 2014 study[8] using the CPCSSN data. The latter study showed that similar validation metrics could be achieved using the CPCSSN data, rather than the charts themselves (which are expensive to access, require a substantial amount of work from the clinics, and involve substantial privacy and security concerns). We employed the revised method, using 1 clinically trained reviewer, rather than 2.

Setting, population and data sources

We used patient chart data from clinics participating in the Southern Alberta Primary Care Research Network (SAPCReN). SAPCReN hosts CPCSSN in southern Alberta.[9] We included data from 13 SAPCReN community-based primary care clinics. These clinics were selected because they had a sufficient number of patients meeting the inclusion criteria to be part of the sample.

We included women and men aged 55 years and older who were registered to a SAPCReN-CPCSSN family physician at the time of data extraction and had been seen by that physician within 2 previous years (Dec. 1, 2014, to Dec. 31, 2016). This criterion was added to ensure that the data included in the record review were reasonably current.

Development of case definition

A case definition for hearing loss in older adults was constructed a priori. First, 1 author (R.M.) reviewed the relevant literature, which included epidemiologic studies using MEDLINE (Ovid interface) and PubMed from 1946 to 2017. The search terms included "hearing loss," "primary care" or "family medicine," and "older adult" in the form of Medical Subject Headings (MeSH) and textword terms for both MEDLINE and PubMed. Additionally, educational and professional publications and websites were searched using a similar approach (Table 1).

Subsequently, we recruited 2 family physicians familiar to the team to determine the keywords, phrases and billing codes a primary care physician might be likely to record in an EMR. One of the authors (R.M.) met individually with each physician in a nonstructured discussion and asked open-ended questions about how they might expect to see hearing loss recorded for an older adult population in the EMR. Examples of questions posed include, "What diagnostic billing codes would you expect to see for a patient with hearing loss?" and "Would physicians be likely to specify the type or location of hearing loss in an older person, or refer to it in a general or nonspecific way?" Finally, a working draft of the case definition was appraised by a speech-language pathologist (T.H.) and audiologist (B.H.) to ensure that all terms and diagnostic codes included were specific to the condition and population in question, to prevent misclassification. Deafness in one or both ears was not included in the case definition without separate reference to hearing loss, as it is difficult to discern whether such cases may be congenital, for example, and thus may be considered a medically distinct phenomenon.[11]

The finalized case definition consisted of a list of terms and diagnostic billing codes (Table 2). The terms comprised both specific and nonspecific diagnoses of hearing loss, for example,

Table 1: List of sources for case definition development search

Name	Type	Reference
American Speech-Language-Hearing Association (ASHA)	Professional association (US)	https://www.asha.org
Canadian Institute for Health Information	Government nonprofit organization (Canada)	https://www.cihi.ca/en
Cochrane Library	Policy institute (UK)	https://www.cochrane.org
MEDLINE/PubMed	Biomedical journal database	https://pubmed.ncbi.nlm.nih.gov/
National Institutes of Health	Government agency (US)	https://www.nih.gov/
Speech-Language & Audiology Canada	Professional association (Canada)	https://www.sac-oac.ca/
Statistics Canada	Government agency (Canada)	https://statcan.gc.ca
World Health Organization	United Nations agency	https://www.who.int

"sensorineural hearing loss," "hearing loss" and "hard of hearing." Reference to an audiologist was not considered sufficient to indicate diagnosis. Although audiometric testing may be performed in primary care settings, it is very infrequently recorded.

Relevant ICD-9 codes included 2 variations of the 388 code (which relates to noise-induced hearing loss and sudden, unspecified hearing loss) as well as 24 variations of the 389 code (which pertains to sensorineural, conductive and mixed hearing loss). Other billing codes included relate to "problems with hearing" (V41.2), "dual sensory impairment" (visual and hearing impairment) (V49.85) and "hearing aid" (V53.2), among others.

The case definition was subsequently translated into a computerized algorithm by a CPCSSN data manager (B.S.), meaning the terms of the case definition were constructed into a set of searchable free-text terms and ICD-9 codes within the CPCSSN database.

Table 2: Case definition for hearing loss in older adults

Text terms and phrases	ICD-9 code	ICD-9 description	Exclusion
"presbycusis"	V41.2	Problems with hearing	None
"sensorineural hearing loss"	V49.85	Dual sensory impairment: blindness with deafness; combined visual hearing impairment	None
"noise-induced hearing loss"	V53.2	Hearing aid	None
"conductive hearing loss"	V72.11	Encounter for hearing examination following failed hearing screening	None
"hard of hearing"	V72.12	Encounter for hearing conservation and treatment	None
"hearing loss"	V80.3	Ear diseases	V72.11–V72.19
"trouble hearing"	388.12	Noise-induced hearing loss	None
"hearing problems"; "problems with hearing"	388.2	Sudden hearing loss, unspecified	None
"perceptive hearing loss"	389	Hearing loss	None
"neural hearing loss"	389	Conductive hearing loss	389.20–389.22
"mixed hearing loss"	389	Conductive hearing loss, unspecified	None
"unspecified hearing loss"	389.01	Conductive hearing loss, external ear	None
	389.02	Conductive hearing loss, tympanic membrane	None
	389.03	Conductive hearing loss, middle ear	None
	389.04	Conductive hearing loss, inner ear	None
	389.05	Conductive hearing loss, unilateral	None
	389.06	Conductive hearing loss, bilateral	None
	389.08	Conductive hearing loss of combined types	None
	389.1	Sensorineural hearing loss: perceptive hearing loss or deafness	388.40–388.44; 389.20–389.22; 306.7
	389.1	Sensorineural hearing loss, unspecified	None
	389.11	Sensory hearing loss, bilateral	None
	389.12	Neural hearing loss, bilateral	None
	389.13	Neural hearing loss, unilateral	None
	389.14	Central hearing loss	None
	389.15	Sensorineural hearing loss, unilateral	None
	389.16	Sensorineural hearing loss, asymmetric	None
	389.17	Sensory hearing loss, unilateral	None
	389.18	Sensorineural hearing loss, bilateral	None
	389.2	Mixed hearing loss, unspecified	None
	389.21	Mixed hearing loss, unilateral	None
	389.22	Mixed hearing loss, bilateral	None
	389.8	Other specified forms of hearing loss	None
	744	Unspecified anomaly of ear with impairment of hearing	None

Note: ICD-9 = *International Classification of Diseases, Ninth Revision*.

Validation of case definition

A random sample of 1000 records was generated from the charts of eligible patients from the 13 SAPCReN community-based primary care clinics included in the study. The sample size of 1000 was chosen to ensure that the confidence interval (CI) for the estimate of sensitivity would be no wider than ± 10%, assuming a prevalence of 10% and a 0.05 level of significance. The number of patient records included from each clinic varied owing to differences in clinic size (larger clinics are likely to have more patients enrolled in their patient panels) and the characteristics of the clinic's patient populations (e.g., clinics with a large proportion of older patients may have had larger numbers of eligible patients than those with more diverse panels).

Manual review of CPCSSN data functioned as the reference standard for this validation. The chart review was completed by a research assistant trained in speech-language pathology who was masked to the algorithm's classification of the data. The chart reviewer was instructed to differentiate between deafness and hearing loss to avoid potential misclassification. The data were recorded in a standardized data abstraction spreadsheet format used previously by Williamson and colleagues[10] and checked for consistency and accuracy after completion (R.M.). Uncertain cases were brought to the study team's audiologist, who was also masked to the outcome of the algorithm. The reference standard also provided the estimation of prevalence.

Statistical analysis

We applied the algorithm to the sample and compared the predicted hearing loss status of patients with the reference standard. Validation analysis consisted of evaluating the output of the case definition algorithm relative to the reference standard and computing the sensitivity, specificity, positive predictive value and negative predictive value. Descriptive statistics based on age, sex and the site from which the patient record was drawn are reported. We analyzed risk factor data using the Fisher exact test and odds ratios. The analyses were performed using the statistical software Stata Intercooled Version 13.

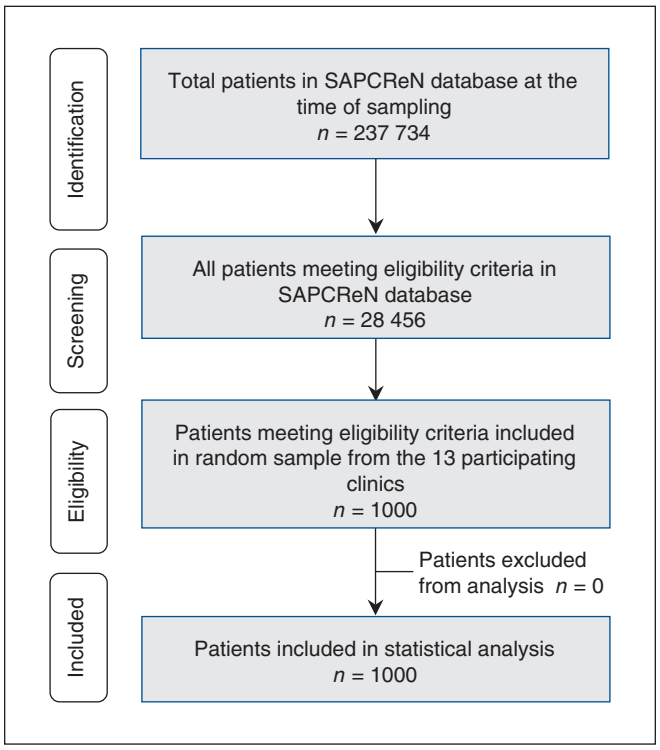

Figure 1: Study flow chart. SAPCReN = Southern Alberta Primary Care Research Network.

Ethics approval

Ethics approval for this study was granted from the University of Alberta Health Research Ethics Board (REB ID: Pro00072964).

Results

A total of 28 456 patients met inclusion criteria for this study (Figure 1). The sample of 1000 records was randomly selected from this patient population. It contained approximately equivalent numbers of men and women (50.4% and 49.6%, respectively). The sample was drawn from 13 SAPCReN sites, with the largest numbers contributed by sites B, C and G (14.7%, 11.1% and 10.6%, respectively). The mean patient age was 67.5 (standard deviation 9.6) years, and the age range was 55–97 years (Table 3).

Table 3: Description of sample included in the validation

Characteristic	No. (%) of patients* n = 1000
Sex, female	496 (49.6)
Age, yr, mean ± SD	67.5 ± 9.6
Site	
A	21 (2.1)
B	147 (14.7)
C	111 (11.1)
D	75 (7.5)
E	84 (8.4)
F	30 (3.0)
G	106 (10.6)
H	55 (5.5)
I	76 (7.6)
J	74 (7.4)
K	55 (5.5)
L	16 (1.6)
M	17 (1.7)
N	45 (4.5)
O	58 (5.8)
P	23 (2.3)
Q	7 (0.7)

Note: SD = standard deviation.
*Unless stated otherwise.

The reference standard identified 61 cases of hearing loss in the sample. Most (n = 34) recordings of hearing loss in the SAPCReN records were nonspecific and typically referred to general hearing loss rather than a specific term (e.g., presbycusis, n = 14). Similarly, the most common diagnostic billing code was 389 (n = 31). This code was included in records with mentions of cerumen (n = 5). A large proportion of patients had no ICD-9 code included at all (n = 12).

When analyzed in comparison with the reference standard, the hearing loss case definition algorithm had sensitivity of 87.3% (95% CI 76.5%–94.4%) and specificity of 94.8% (95% CI 93.1%–96.1%). The positive predictive value was comparatively low at 52.9% (95% CI 42.8%–62.8%), though the negative predictive value was high at 99.1% (95% CI 98.2%–99.6%) (Tables 4 and 5).

Based on the reference standard, the prevalence of hearing loss within our sample was found to be 6.3% (95% CI 4.9%–7.9%) (Table 5). The average age within the hearing loss case set was notably higher than that of the sample population, with a mean of 73.7 (SD 9.5) years. Older age as a risk factor for hearing loss was found to be significant (t = 4.98, 95% CI 3.76–8.65) (Table 6). The case set also had a greater proportion of men than women, at 61.9% and 38.1%, respectively, with a corresponding odds ratio for male sex compared with female sex of 1.65 (95% CI 0.98–2.79). The largest proportion of hearing loss cases were contributed by sites B, C, E and H (15.8% for site B and 12.7% for sites C, E and H).

Table 4: Comparison of reference standard with case definition algorithm

Reference standard	Algorithm		
	Positive	Negative	Total
Positive	55	8	63
Negative	49	888	937
Total	104	896	1000

Table 5: Summary of the validation metrics

Validation metric	% (95% CI)
Prevalence	6.3 (4.9–7.9)
Sensitivity	87.3 (76.5–94.4)
Specificity	94.8 (93.1–96.1)
Positive predictive value	52.9 (42.8–62.8)
Negative predictive value	99.1 (98.2–99.6)

Note: CI = confidence interval.

Table 6: Hearing loss risk factors

Characteristic	Cases of hearing loss	Odds ratio* (95% CI)
Sex, no. (%)		
Female (n = 496)	24 (4.8)	0.61 (0.36–1.02)
Male (n = 504)	39 (7.7)	1.65 (0.98–2.79)
Age, yr, mean ± SD	73.7 ± 9.5	t = 4.98 (3.76–8.65)

Note: CI = confidence interval, SD = standard deviation.
*Unless stated otherwise.

Interpretation

The high sensitivity and specificity of the case definition suggest that it is an appropriate candidate for surveillance or use in future epidemiologic studies.

There is divergence between the prevalence of physician-recorded hearing loss in this sample and other prevalence estimates in which diagnostic testing was performed. Although the issue of misclassification in clinically extracted data of any type is complex and far-reaching, it would be erroneous to attribute the large disparity in prevalence to misclassification of the case definition alone. First, our study focuses on patient-reported, physician-recorded hearing loss in primary care settings. Findings of the 2012/2013 Canadian Health Measures Survey suggest low prevalence resulting from underreporting of hearing loss.[1] Furthermore, the study undertaken by Halpin and colleagues[5] also lends evidence to the conclusion that physicians in our sample may underrecord hearing loss symptoms. This would suggest the potential for population-based prevalence estimates to be larger given that studies employing an audiometric measurement for hearing loss (rather than patient-reported hearing loss) will capture cases that are of lower severity.[12,13] Patients with less severe hearing loss are less likely to experience substantial disruption to their life as a result of hearing loss and are therefore less likely to raise their concerns with their primary care physician.

The US Armed Forces Health Surveillance Center case definition for noise-induced, occupational hearing loss using EMR data, which consisted of ICD-9 codes, does not indicate whether it has been employed to estimate prevalence.[6] Although limiting the case definition to diagnostic billing codes serves the purpose of ensuring the case definition is necessarily specific and limits the occurrence of false positives, there are problems with this approach. Usage of diagnostic billing codes such as ICD-9 can be inconsistent between EMR software and health care providers. Moreover, diagnostic billing codes attached to a patient encounter may not accurately describe the physician's diagnoses, particularly in cases in which more than 1 condition is discussed. For example, the code 389 was in several instances included in records with mentions of cerumen. Since 389 is a code referring to loss of hearing (including but not limited to sensorineural hearing loss) rather than the presence of cerumen in the ear (for which a distinct code, 380.4, is specified), cause must in some cases remain speculative. Overall, our prevalence estimate suggests that there may be a disparity between the prevalence of hearing loss in the community-dwelling, older adult population

and the frequency with which physicians are recording hearing loss in EMRs for these types of patients.

This broad, inclusive case definition serves as a starting point for examining the population of older adults with hearing loss in primary care.

Limitations

Development of the case definition included consultation with family physicians; however, these discussions were conducted informally, without a standard list of questions.

This case definition does not indicate chronic hearing loss versus temporary hearing loss, and does not assess severity. Although the ICD-9 code 388.2 was included in the case definition to capture hearing loss related to inner ear problems or Meniere disease, this code may also refer to temporary hearing loss caused by otitis media or cerumen impaction. The relatively low positive predictive value reported here limits the applicability of this case definition to epidemiologic (rather than to individual patient) identification or cohort development purposes. However, prevalence in our sample was low, which may have in turn influenced the low positive predictive value.

This study reports a low prevalence rate relative to community-based studies, which may reflect differential recording or reporting of hearing loss. Furthermore, there is potential for misclassification from variation in data recorded by physicians relating to the format of the EMR in usage.

Our study employed 1 trained reviewer in the creation of the reference standard; therefore, it was not possible to assess accuracy in the form of interrater reliability. However, we did have uncertain cases reviewed by an audiologist who was masked to the algorithm outcome. The study was limited to data from a practice-based research network in Alberta. Further investigation may be helpful to determine how well the case definition performs across Canada.

Conclusion

This validation of a case definition for hearing loss in the EMRs of older adults may contribute to improving and further understanding older adult hearing loss in primary care settings as well as for use of primary care data in epidemiologic studies.

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