Alzheimer's disease mortality among taxi and ambulance drivers: population based cross sectional study

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ABSTRACT

OBJECTIVE

To analyze mortality attributed to Alzheimer's disease among taxi drivers and ambulance drivers, occupations that demand frequent spatial and navigational processing, compared with other occupations.

DESIGN

Population based cross-sectional study.

SETTING

Use of death certificates from the National Vital Statistics System in the United States, which were linked to occupation, 1 January 2020-31 December 2022.

PARTICIPANTS

Deceased adults aged 18 years and older.

MAIN OUTCOMES MEASURES

Among 443 occupations studied, percentage of deaths attributed to Alzheimer's disease for taxi drivers and ambulance drivers and each of the remaining 441 occupations, adjusting for age at death and other sociodemographic factors.

RESULTS

Of 8 972 221 people who had died with occupational information, 3.88% (348 328) had Alzheimer's disease listed as a cause of death. Among taxi drivers, 1.03% (171/16 658) died from Alzheimer's disease, while among ambulance drivers, the rate was 0.74% (10/1348). After adjustment, ambulance drivers (0.91% (95% confidence interval 0.35% to 1.48%)) and taxi drivers (1.03% (0.87% to 1.18%)) had the lowest proportion of deaths due to Alzheimer's disease of all occupations examined. This trend was not observed in other transportation related jobs that are less reliant on real time spatial and navigational processing or for other types of dementia. Results were consistent whether Alzheimer's disease was recorded as an underlying or contributing cause of death.

CONCLUSIONS

Taxi drivers and ambulance drivers, occupations involving frequent navigational and spatial processing, had the lowest proportions of deaths attributed to Alzheimer's disease of all occupations.

WHAT IS ALREADY KNOWN ON THIS TOPIC

The hippocampus is one of the first brain regions to atrophy in Alzheimer's disease, leading to substantial cognitive decline as the disease progresses

The hippocampus is a brain region used for spatial memory and navigation and has been shown to be enhanced in taxi drivers compared with the general population

WHAT THIS STUDY ADDS

In an analysis of nearly all death certificates in the United States, taxi drivers and ambulance drivers, whose jobs require frequent spatial and navigational processing, were found to be the occupations with the two lowest risk adjusted percentages of deaths due to Alzheimer's disease

Our findings raise the possibility that frequent navigational and spatial processing tasks, as performed by taxi and ambulance drivers, might be associated with some protection against Alzheimer's disease

Introduction

Deaths attributed to Alzheimer's disease have doubled over the past three decades and will likely increase as the population ages.[1] Despite decades of research, an important gap remains in the development of definitive treatment or prevention strategies.[2] A landmark neuroimaging study showed that taxi drivers in London, UK, developed enhancing functional changes in the hippocampus.[3] The hippocampus is the brain region involved in both the creation of cognitive spatial maps and the development of Alzheimer's disease,[4 5] which is associated with accelerated hippocampal atrophy.[6] This finding raises the possibility that occupations that demand frequent spatial processing, such as taxi driving, may be associated with decreased Alzheimer's disease mortality.

To investigate this possibility, we leveraged population based US mortality data, which include newly linked information on the occupation of people who had died, to evaluate Alzheimer's disease mortality across various professions. We hypothesized that occupations such as taxi driving and ambulance driving (but not emergency medical technicians (or EMTs)), which demand frequent real time spatial and navigational processing, might be associated with a reduced burden of Alzheimer's disease mortality compared with other occupations.

Methods

Data sources

Mortality data were obtained from the National Vital Statistics System, a population based registry of all deaths in the US from 1 January 2020-31 December 2022. These data are based on death certificates, which include the underlying cause of death, coded according to the International Classification of Diseases, 10th revision (ICD-10), and sociodemographic information of the deceased individuals (eg, age, sex, race, ethnic group, and educational attainment).[7]

Additionally, death certificates included a field for reported usual occupation (the occupation in which the decedent spent most of their working life), generally completed by a funeral director with help from the decedent's informant. Starting in 2020, occupation narratives from death certificates were coded to standardized 2010 US Census Bureau

Table 1 | Characteristics of decedents with reported navigational occupation

Characteristics	Ambulance drivers(n=1348)	Taxi drivers and chauffeurs (n=16 658)	Aircraft pilots (n=8465)	Bus drivers (n=43 295)	Ship captains (n=4199)	All other occupations (n=8 898 256)
Age, mean, years (SD)	64.2 (14.7)	67.8 (14.5)	78.1 (13.3)	74.0 (12.3)	72.6 (14.2)	74.3 (16.1)
Sex, no. (%):						
Female	296 (22.0)	1730 (10.4)	248 (2.9)	21 552 (49.8)	96 (2.3)	4 264 793 (48.3)
Male	1052 (78.0)	14 928 (89.6)	8217 (97.1)	21 743 (50.2)	4103 (97.7)	4 565 601 (51.7)
Race and ethnicity, no. (%):						
Asian or Pacific Islander	42 (3.1)	1200 (7.2)	110 (1.3)	546 (1.3)	120 (2.9)	206 847 (2.4)
Black	344 (25.5)	4301 (25.8)	143 (1.7)	11 370 (26.3)	115 (2.7)	986 628 (11.4)
Hispanic	205 (15.2)	2904 (17.4)	228 (2.7)	3171 (7.3)	122 (2.9)	691746 (8)
Other	60 (4.5)	210 (1.3)	58 (0.7)	622 (1.4)	69 (1.6)	58 489 (0.7)
White	697 (51.7)	8043 (48.3)	7926 (93.6)	27 586 (63.7)	3773 (89.9)	6 695 410 (77.5)
Educational attainment, no. (%):						
Less than high school	222 (16.5)	3494 (21.0)	120 (1.4)	7211 (16.7)	897 (21.4)	1 457 733 (17)
High school or GED degree	710 (52.7)	8414 (50.5)	1759 (20.8)	26 197 (60.5)	1851 (44.1)	3 818 270 (44.5)
Some college or associate degree	319 (23.7)	2920 (17.5)	2607 (30.8)	7969 (18.4)	854 (20.3)	1 713 778 (20)
Bachelor's degree	66 (4.9)	1311 (7.9)	3194 (37.7)	1408 (3.3)	454 (10.8)	971 517 (11.3)
Graduate degree	16 (1.2)	240 (1.4)	735 (8.7)	226 (0.5)	111 (2.6)	577 116 (6.7)
Unknown	15 (1.1)	279 (1.7)	50 (0.6)	284 (0.7)	32 (0.8)	39 282 (0.5)

GED=general educational development.

occupation codes in collaboration with the National Institute for Occupational Safety and Health.[8] These data for usual occupation were available for 46 states in 2020 (all except Iowa, Arizona, North Carolina, and Rhode Island), 49 states in 2021 (all except Rhode Island), and 50 states and Washington, DC in 2022, covering approximately 98% of the US population in 2020-2022.

Study population

Our final dataset included 443 occupational groups (supplemental appendix). We focused on taxi drivers (occupation code: 9140 (taxi drivers and chauffeurs)) and ambulance drivers (9110 (ambulance drivers and attendants, except emergency medical technicians)) as occupations involving extensive day-to-day navigation, with often unpredictable, real time navigational demands. All other occupations formed a comparison group. We also focused on bus drivers (occupation code: 9120), aircraft pilots (9030), and ship captains (9310 (ship and boat captains and operators)), as a more specific comparison group because these are still considered transportation based occupations but require relatively little navigational demands due to their reliance on predetermined routes. We excluded people with unknown occupational data (4.8% of population studied). We also excluded students attending high school or college (occupation code: 9070), and occupations with fewer than 250 overall deaths per year (as these indicate relatively rare or emerging occupations).

Outcome

The primary outcome was the percentage of deaths for each occupation with underlying cause of death from Alzheimer's disease (ICD-10 code G30).

Statistical analysis

For each occupation, we first calculated the percentage of deaths due to Alzheimer's disease and the mean age at death in years (ie, average life expectancy). We plotted the association between these two variables, with each observation reflecting a single occupation. The purpose of this analysis was to illustrate the need to account for the person's age at death since the risk of Alzheimer's disease rises with age and therefore Alzheimer's mortality would naturally be lower in occupations with a lower life expectancy.[9]

We then used multivariable logistic regression at the individual level to estimate risk adjusted percentages of deaths from Alzheimer's disease for each occupation, adjusting for age at death (indicator variables for each year of age), sex (male or female), race and ethnic group (black, white, Hispanic, Asian or Pacific Islander, other

Table 2 | Deaths attributed to Alzheimer's disease by occupation

Occupation	Deaths, no.	Alzheimer's deaths, no.	Alzheimer's deaths, %	Alzheimer's deaths, adjusted % (95% CI)	Adjusted odds ratio (95% CI)	P value
Ambulance drivers	1348	10	0.7	0.91 (0.35 to 1.48)	0.50 (0.27 to 0.93)	0.03
Taxi drivers and chauffeurs	16 658	171	1.0	1.03 (0.87 to 1.18)	0.56 (0.48 to 0.66)	<0.01
Bus drivers	43 295	1345	3.11	1.65 (1.56 to 1.74)	0.91 (0.85 to 0.97)	0.01
Chief executives	54 873	2251	4.10	1.82 (1.74 to 1.90)	1 (reference)	
Ship captains	4199	117	2.79	2.12 (1.73 to 2.50)	1.17 (0.97 to 1.41)	0.11
Aircraft pilots	8465	387	4.57	2.34 (2.11 to 2.58)	1.30 (1.16 to 1.45)	<0.01

Risk adjusted percentages and mortality odds ratios were adjusted for age at death, sex, race, ethnic group, and educational attainment using logistic regression. Adjusted odds ratios were calculated using chief executives (US Census Bureau occupation code 0010) as an arbitrary reference group.

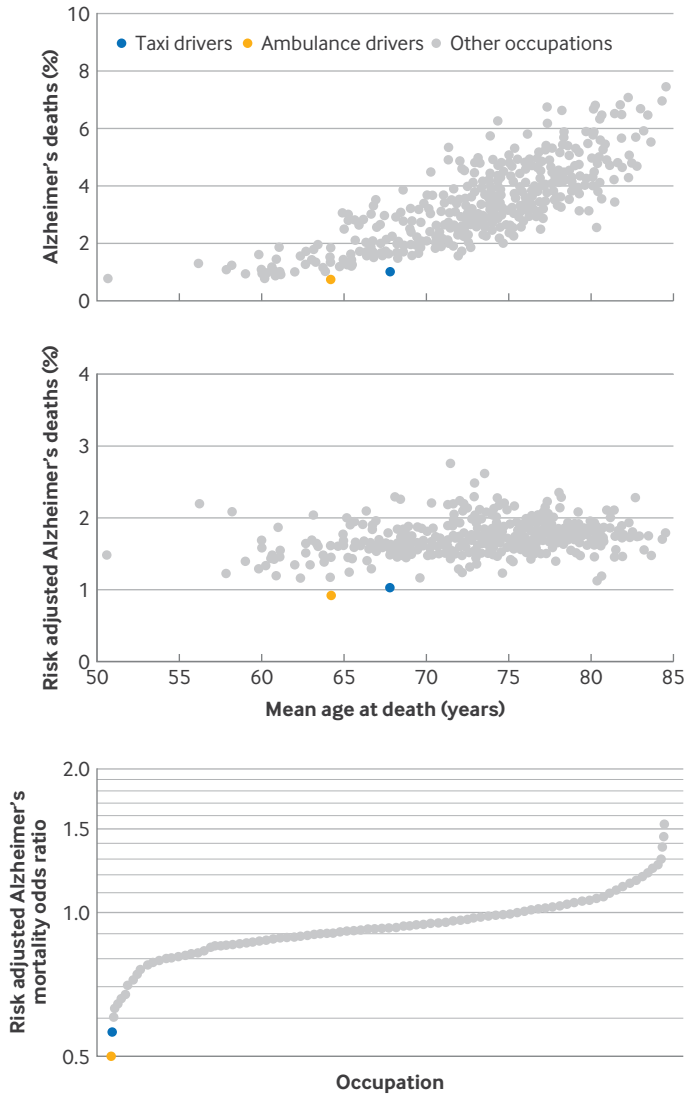

Fig 1 | Mortality from Alzheimer's disease among ambulance drivers, taxi drivers, and other occupations. Risk adjusted percentages and mortality odds ratios were adjusted for age at death, sex, race, ethnic group, and educational attainment using logistic regression. In the bottom graph, a logarithmic scale was used for the y axis to allow for accurate visual comparison of effect sizes between occupations, as the logarithmic scale equalizes the distances between ratios and their reciprocals. Adjusted odds ratios were calculated using chief executives (US Census Bureau occupation code 0010) as an arbitrary reference group

race), and educational attainment (indicator variables for <8th grade, 9-12th grade, high school, college, master's or doctorate). Mortality odds ratios from the multivariable model were also ranked from lowest to highest across occupations to facilitate identification of occupations with the lowest risk of death from Alzheimer's disease; chief executive (occupation code: 0010) was arbitrarily chosen as the reference group in regression models.

We performed four sensitivity analyses to assess the robustness of our comparisons.[10] Firstly, we repeated analyses among people who died after age 60 years, to capture the age range most typical of Alzheimer's disease onset and mortality.[11] Secondly, we broadened the definition of Alzheimer's disease mortality to include Alzheimer's disease as an underlying or contributing cause of death on the death certificate. Thirdly, we assessed Alzheimer's disease mortality among bus drivers, aircraft pilots, and ship captains (transportation-based occupations with relatively fewer real time navigational demands due to frequently predetermined routes that may not lead to similar hippocampal changes).Fourthly, we evaluated deaths with underlying causes from other forms of dementia where the associated pathophysiology is not focused on the hippocampus: vascular dementia (ICD-10 code F01) and unspecified dementias (F03). The purpose of this falsification analysis was to examine whether factors specific to occupation among taxi and ambulance drivers (ie, confounders) might affect dementia mortality generally, which would suggest an alternative to hippocampal mediated changes in Alzheimer's disease mortality.[12]

Analyses were performed using Stata version 18.0 (StataCorp LLC) and MATLAB 2024a (MathWorks, Inc.). The 95% confidence intervals around estimates in adjusted analyses reflects an α level of 0.025 in each tail ($P \leq 0.05$). The study, which relied on publicly available data, was considered exempt from review by the Institutional Review Board at Harvard Medical School.

Patient and public involvement

This study was a retrospective observational study. Patients were not involved in setting the research question or the outcome measures or advising on interpretation of or writing up results. The study was unfunded and therefore no funding was available for patient and public involvement.

Results

We identified a total of 8 972 221 people who had died and who had occupational information. Measured characteristics of the population by occupational group are reported in table 1. Of the selected navigational occupations, lowest mean age at death was 64.2 years (standard deviation 14.7) in ambulance drivers and 67.8 years (14.5) in taxi drivers. These occupations were of predominantly men with the exception of bus drivers where the split between sexes was more even. Other than aircraft pilots who had a higher education level, most people in navigational occupations had a high school education or less.

Of all people studied, 3.88% (348 328/8 972 221) were identified as having an underlying cause of death from Alzheimer's disease. The unadjusted percentage of deaths from Alzheimer's disease was 1.03% (171/16 658) among taxi drivers and 0.74% (10/1348) among ambulance drivers; and was 3.11% (1345/43 295) for bus drivers, 4.57% (387/8465) for pilots, and 2.79% (117/4199) for ship captains (table 2). Notably, deaths from underlying cause of Alzheimer's disease were lower for taxi and ambulance

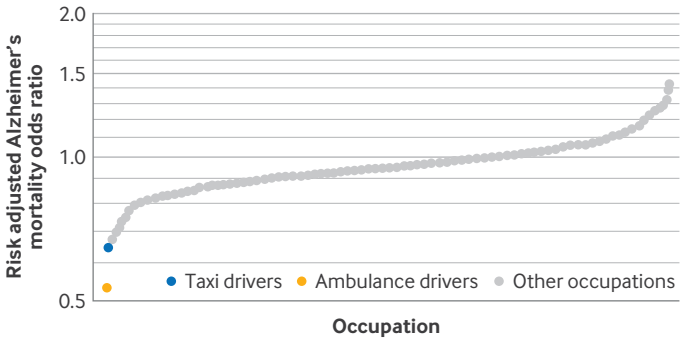

Fig 2 | Mortality from Alzheimer's disease as underlying or contributing cause of death by occupation. Risk adjusted mortality odds ratios were adjusted for age at death, sex, race, ethnic group, and educational attainment using logistic regression A logarithmic scale was used for the y axis to allow for accurate visual comparison of effect sizes between occupations, as the logarithmic scale equalizes the distances between ratios and their reciprocals. Adjusted odds ratios were calculated using chief executives (US Census Bureau occupation code 0010) as an arbitrary reference group

drivers than for other occupations with a similar mean age at death (fig 1, top graph).

We adjusted for age at death, sex, race, ethnic group, and educational attainment. Of 443 occupations considered, the two occupations with the lowest adjusted percentage of deaths from Alzheimer's disease were ambulance drivers (0.91% (95% confidence interval (CI) 0.35% to 1.48%)) and taxi drivers (1.03% (0.87% to 1.18%)) (fig 1, middle graph). By contrast, the adjusted percentage of deaths from Alzheimer's disease for the general population was 1.69% (95% CI 1.66% to 1.71%), with P<0.001 for comparison to ambulance drivers and P<0.001 for comparison to taxi drivers. Similarly, across all occupations the adjusted odds ratio of death from Alzheimer's disease was lowest among taxi and ambulance drivers (fig 1, bottom graph; odds ratio 0.56 (95% CI 0.48 to 0.65) for both categories combined relative to chief executives).

In sensitivity analyses, ambulance and taxi drivers consistently had the lowest proportional Alzheimer's disease mortality when restricting our analysis to individuals who died aged 60 years or older (supplemental figure 1) and when Alzheimer's disease was specified as either an underlying or contributing cause of death (fig 2). The pattern of lower Alzheimer's disease mortality was not observed in other occupations related to transportation with fewer navigational demands (fig 3). For instance, aircraft pilots and ship captains ranked as having the 4th and 23rd highest adjusted Alzheimer's disease mortality, out of 443 occupations, while bus drivers ranked 263rd. The adjusted percentage of deaths from Alzheimer's disease for bus drivers was 1.65 (95% CI 1.56 to 1.74) (P<0.001 for comparisons to ambulance drivers and taxi drivers, respectively), for pilots was 2.34 (2.11 to 2.58) (P<0.001 for comparisons to ambulance drivers and taxi drivers), and for ship captains was 2.12 (1.73 to 2.50) (P<0.001 for comparisons to ambulance drivers and taxi drivers). Finally, the pattern of low Alzheimer's disease mortality among taxi and ambulance drivers was not observed when forms of dementia (vascular and unspecified) other than Alzheimer's disease were evaluated, suggesting the possibility of changes mediated by the hippocampus in taxi and ambulance drivers lowering Alzheimer's disease risk (fig 4).

Discussion

Principal findings

This population based study in the US found that taxi and ambulance drivers, whose occupations require substantial navigational memory, had the lowest Alzheimer's disease mortality of all occupations. One hypothetical explanation of this notable finding is that these occupations are associated with neurological changes (in the hippocampus or elsewhere) that reduce Alzheimer's disease risk.

The original study that motivated this study was based on hippocampal changes in London taxi drivers.[12] Although cognitive demands on London taxi drivers are unique due to "The Knowledge", requiring intensive training and an exam of navigating the city,[13] the core aspects of spatial navigation and frequent complex navigational tasks are also central to the role of US taxi drivers, at least historically. Consistent with our findings, a follow-up study of London bus drivers did not show the same hippocampal changes as in taxi drivers, possibly due to the pre-determined nature of bus drivers' routes.[3] If a hypothetical link between hippocampal changes in taxi drivers and future risk of death from Alzheimer's disease exists, our findings among US taxi and bus drivers are consistent with studies of hippocampal changes (or lack thereof) among their London counterparts.

Strengths and limitations of this study

Importantly, our study design has several limitations that limit causal inference and result in the possibility of other explanations, including unmeasured confounding from biological, social, or administrative factors. Firstly and perhaps most importantly, selection bias is possible because individuals who are at higher risk of developing Alzheimer's disease may be less likely to enter or remain in memory intensive driving occupations such as taxi and ambulance driving. This could mean that the lower Alzheimer's disease mortality observed in these occupations is not due to the protective effect of the job itself but rather because those prone to the disease may have self-selected out of such roles. However, Alzheimer's disease symptoms typically develop after patients' working years, with only 5-10% of cases occurring in people younger than 65 years (early onset).[11 14] While subtle symptoms could develop earlier, they would still most likely be after a person had worked long enough to deem the occupation to be a so-called usual occupation, suggesting against substantial attrition from navigational jobs due to

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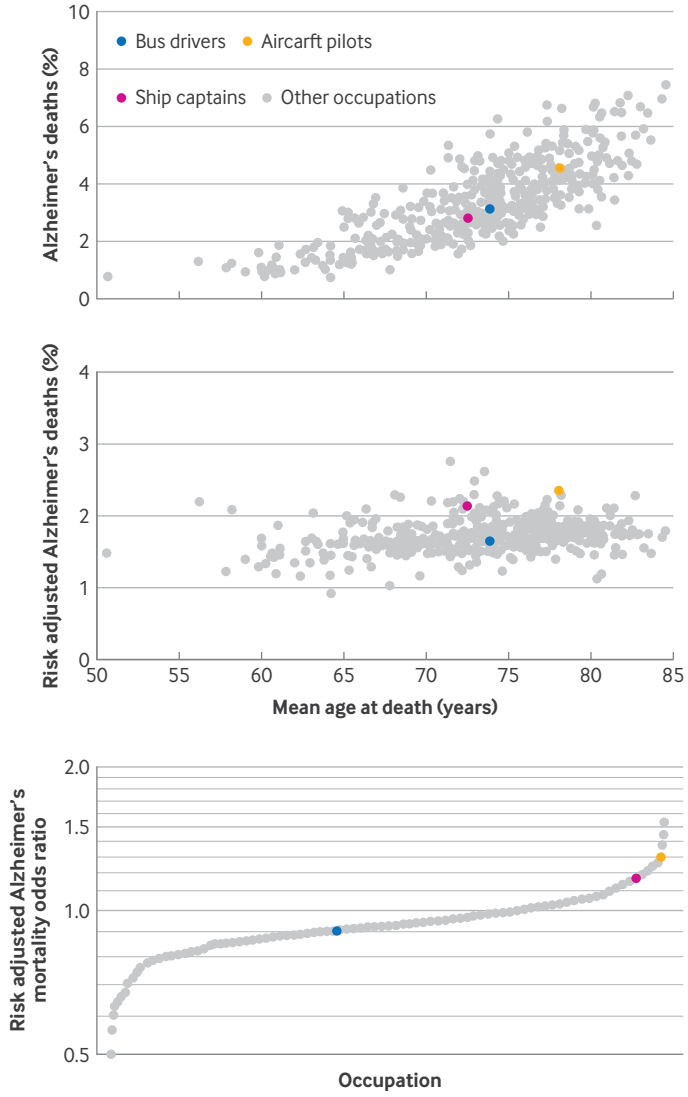

Fig 3 | Mortality from Alzheimer's disease among bus drivers, aircraft pilots, ship captains, and other occupations. Risk-adjusted percentages and mortality odds ratios were adjusted for age at death, sex, race, ethnicity, and educational attainment using logistic regression. In the bottom graph, a logarithmic scale was used for the y axis to allow for accurate visual comparison of effect sizes between occupations, as the logarithmic scale equalizes the distances between ratios and their reciprocals. Adjusted odds ratios were calculated using chief executives (US Census Bureau occupation code 0010) as an arbitrary reference group

development of Alzheimer's disease. Moreover, even if lifelong taxi driving selects for individuals with strong spatial processing, our findings would still suggest an interesting link between spatial processing skills and risk of Alzheimer's disease.

Secondly, our study assumed that an individual's usual occupation at the time of death reflects a large portion of their working life, despite the fact that most people hold multiple jobs throughout their lifetime. However, usual occupation has been shown to be a reliable proxy for current occupation.[15] To the extent that the data contain classification errors, the data would be much more likely to classify individuals who spent significant time in a navigational job as having other usual occupations. If this classification were to lead to bias, the differences between navigational and non-navigational occupations would be underestimated. Furthermore, this bias would be unlikely to specifically apply to Alzheimer's disease and not to other forms of dementia.

Thirdly, death certificates likely underestimate the number of deaths caused by Alzheimer's disease and the degree of underestimation may vary by occupation. The preservation of navigational memory or skills among taxi and ambulance drivers may simply lead clinicians to slightly discount the possibility of Alzheimer's disease in these patients, which could lead to a lower observed proportion of deaths with a reported underlying or contributing cause of Alzheimer's disease. Similarly, taxi or ambulance drivers may be disincentivized to seek evaluation for symptoms out of concern for job security, which may also lead to underdiagnosis of Alzheimer's disease. However, these diagnostic biases would likely affect mortality for all dementias, not just Alzheimer's disease, and would also need to apply only to taxi and ambulance drivers to explain our findings, and not to other occupations related to transportation such as bus drivers, aircraft pilots, or ship captains.

Fourthly, analyses of mortality records are likely to underestimate Alzheimer's disease prevalence as its contribution to mortality is complex and more proximal causes may be reported on death certificates. However, any diagnostic error in this study is unlikely to differ across occupation groups; furthermore, we observed similar results when including Alzheimer's disease as a contributing, rather than underlying, cause of death and we did not find the same results with other forms of dementia.

Finally, the study analyzed the proportions of deaths attributed to Alzheimer's disease rather than measures such as the standardized mortality rate due to the unavailability of reliable population based denominators by occupation. Although proportional mortality analyses do not provide information about the population at risk, with careful selection of controls and risk adjustment for factors that may affect competing risks (eg, age, sex, and social class), these values can still serve as a useful indicator of variations in disease frequency across different occupations.[16 17]

Conclusions

Our large scale epidemiological findings raise novel questions about the linkage between taxi and ambulance driving and Alzheimer's disease mortality. While these findings suggest a potential link between the demands of these occupations and reduced Alzheimer's disease risk, this study design does not permit interpretation of a causal effect between occupations and risk of Alzheimer's disease mortality or neurological changes in the hippocampus. We view these findings not as conclusive, but as hypothesis generating. Further research is necessary

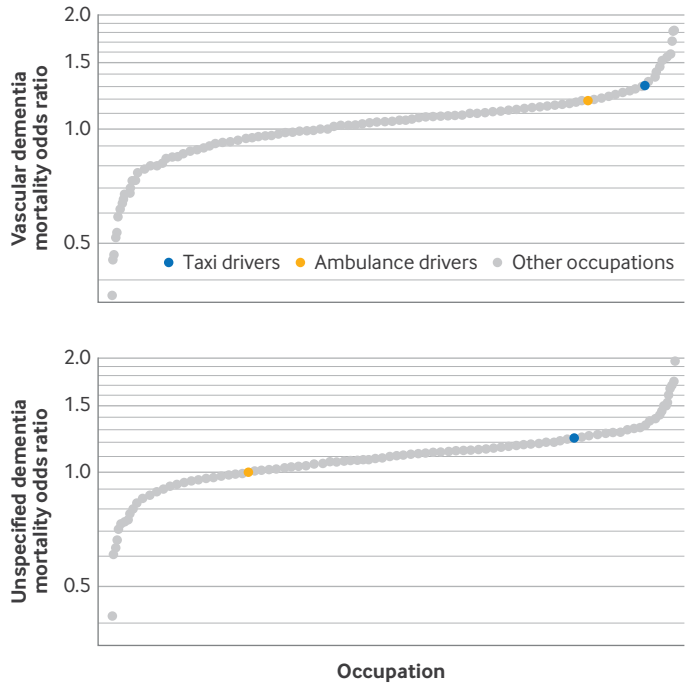

Fig 4 | Mortality from other forms of dementia among ambulance drivers, taxi drivers, and other occupations. Risk-adjusted mortality odds ratios were adjusted for age at death, sex, race, ethnicity, and educational attainment using logistic regression A logarithmic scale was used for the y axis to allow for accurate visual comparison of effect sizes between occupations, as the logarithmic scale equalizes the distances between ratios and their reciprocals. Adjusted odds ratios were calculated using chief executives (US Census Bureau occupation code 0010) as an arbitrary reference group

to definitively conclude whether the spatial cognitive work required for these occupations affect risk of death from Alzheimer's disease and whether any cognitive activities can be potentially preventive.

Contributors: All authors contributed to the design and conduct of the study, data collection and management, analysis interpretation of the data; and preparation, review, or approval of the manuscript. ABJ supervised the study and is the guarantor. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

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Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/disclosure-of-interest/ and declare: funding to CMW by the Agency for Healthcare Research and Quality; no financial relationships with any organizations that might have an interest in the submitted work in the previous three years; and no other relationships or activities that could appear to have influenced the submitted work. ABJ reports receiving (in the past 36 months) consulting fees unrelated to this work from Analysis Group. ABJ also reports receiving (in the past 36 months) income unrelated to this work from hosting the podcast Freakonomics, MD, from book rights to Doubleday Books, and authorship income from *The New York Times*, *The Wall Street Journal*, and *Los Angeles Times*. CMW reports receiving (in the past 36 months) consulting fees unrelated to this work from Alosa Health, Analysis Group, Atheneum, Berkshire Hathaway Home Companies, Chronius, FVC Health, GLG, Guidepoint, NuvoAir, Ogilvy, Philips, Simbo, Substack, Tell Health, *The New York Times*, and *The Wall Street Journal*, and income unrelated to this book from book rights to Doubleday Books.

Ethical approval: The study relied on publicly available data and was considered exempt from review by the institutional review board at Harvard Medical School.

Data sharing: Data are publicly available.

Transparency: The lead author (the manuscript's guarantor) affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Dissemination to participants and related patient and public communities: This study was a retrospective observational study. The results of this work will be disseminated to the public through institutional press releases, ensuing news articles, and an opinion piece authored by the study's authors that describe the study's findings for the public.

Provenance and peer review: Not commissioned; externally peer reviewed.

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