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Hospitalization and Alzheimer's Disease: Results From a Community-Based Study

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Background. Prior studies offer conflicting findings on whether Alzheimer's disease (AD) is associated with an increased risk of hospitalization.

Methods. We investigated AD and hospitalization in the Washington Heights–Inwood Columbia Aging Project (WHICAP), a community-based study of 2,334 elders in New York City. In 1996, an electronic medical records system was established that allows an e-mail alert to be sent to the research team whenever WHICAP subjects are admitted to Columbia-Presbyterian Medical Center (CPMC), the site of hospital care for the majority of subjects.

Results. Of the WHICAP cohort, 13.1% was admitted to CPMC in 21 months of follow-up; 17.5% of AD patients and 11.9% of unaffected subjects were admitted ($p < .01$). Multivariate logistic regression models showed that more advanced AD (Clinical Dementia Rating scale 3+) was a significant risk factor for hospitalization independently of age, gender, education, comorbid medical conditions, and death in the follow-up period (OR 2.3; 95% CI: 1.1, 4.6); subjects with mild or moderate AD did not show a significantly elevated risk. The prevalence of psychiatric symptoms did not differ between AD subjects who were hospitalized in the reporting period and AD subjects who were not hospitalized. Infectious disease was a more common discharge diagnosis for subjects with AD ($p < .05$).

Conclusions. In this community-based cohort, subjects with severe AD were more likely to be hospitalized than unaffected subjects. The increased use of hospital care by these AD patients appears to be specific to AD but is not a result of psychiatric morbidity or end-of-life care. Rather, a greater risk of medical complications that require hospital care, especially infections, appears to be characteristic of severe AD.

ALZHEIMER'S disease (AD) is a common disease of late life, affecting 5%–10% of the population aged 65 and older (1). However, the significance of AD for use of health services has only recently become a topic of research. Prior studies offer conflicting findings on whether AD is associated with an increased risk of hospitalization relative to unaffected elders. These studies have reported greater hospital utilization (2,3) but also no differences or even lower use (4,5). A clearer understanding of the association between AD and hospitalization would be valuable for determining the cost of AD care and also for assessing whether people with AD are at risk for receiving less aggressive medical care than other elders (6).

The Washington Heights–Inwood Columbia Aging Project (WHICAP) offers important data on AD and risk of hospitalization. A total of 2,334 older adults were enrolled in the study in 1992, with follow-up assessments in 1994–95 ($n = 1520$) and 1996–97 ($n = 1145$). At each follow-up, subjects received neuropsychological, neurologic, and functional assessments, allowing diagnosis of AD in accord with standardized criteria (7). In this area of New York City, the majority of hospital care is provided by a single hospital, Columbia-Presbyterian Medical Center (CPMC). Beginning in 1996, an electronic medical records system was established for WHICAP participants. In this system, every hospital admission of a WHICAP subject is flagged, with an electronic mail "alert" sent to the research team. Thus, ascertainment of CPMC hospitalization in this cohort is complete for the period corresponding to the second follow-up survey.

The WHICAP cohort, then, offers important advantages for examining AD and hospitalization. Actual hospital admission data (as opposed to self- or proxy reports) are available, as well as actual diagnoses of AD (as opposed to results from cognitive screening tests alone). Moreover, the geography and limited medical care of the region link the cohort, for the most part, to a single hospital.

Methods

Sample

Subjects recruited into WHICAP came from two sources: a stratified random sample drawn from Health Care Financing Administration (HCFA) eligibility files ($n = 2124$), and targeted recruitment of elders with cognitive impairment drawn from a case reporting system of elders receiving services ($n = 210$). Sampling strata for this survey included age (65–74, 75–84, 85+), gender, and race-ethnicity (Hispanic, non-Hispanic black, non-Hispanic white). For the HCFA-based survey, systematic replicate subsamples were drawn using random starts, such that each subsample contained age and racial-ethnic groups of equal size. The response rate for the entire sample at baseline was 70% (8–10).

All WHICAP subjects alive at the beginning of the hospital reporting period (January, 1996) were included in this study ($N = 2003$). These subjects represent 85.8% of the original cohort.

Measures

Alzheimer's disease status.—All WHICAP subjects completed a full battery of neuropsychological tests. Subjects meeting neuropsychological criteria for AD (7,11,12) were examined by a neurologist. In addition, a random sample of 25% of nonde-

mented subjects were also examined by neurologists. Severity of AD was staged according to the Clinical Dementia Rating (CDR) scale (13). In this staging system, physicians rate patient function along six dimensions and derive a composite score indicating mild, moderate, severe, profound, or terminal disease. We divided subjects with AD into two groups, those with mild-moderate disease (CDR 1-2) and those with more severe disease (CDR 3+). For these analyses, we used the last diagnosis available. Of the total WHICAP cohort, 1,978 (98.8%) were diagnosed.

Hospitalization event monitoring system.—The hospital admissions period monitored extended from January 1, 1996, to September 30, 1997, a period of 21 months. The CPMC electronic reporting system documented subjects' admissions, length of stay for each admission, and discharge diagnoses. The e-mail alert program was created by the CPMC Department of Medical Informatics as part of an effort to use medical records more effectively for clinical and epidemiological research. Once an alert was received, subjects' hospital stays were monitored; research physicians reviewed patients' charts and coded discharge diagnoses into 1 of 11 categories: surgery, metabolic/nutritional disorders, trauma, pneumonia, other infections, cardiovascular disease, cerebrovascular disease, malignancy, hip fracture, other, or unknown.

Number of hospitalizations was recorded for each subject, along with a dichotomous variable indicating "no" or "any" hospitalization in the reporting period. Length of stay was calculated by summing the number of days spent in the hospital across discrete admissions.

Reported hospitalizations: concurrent second follow-up survey.—During the period in which CPMC hospitalizations were electronically monitored, the WHICAP sample also underwent a concurrent, second follow-up survey assessment, in which information was collected from 1,145 respondents or their proxies. At this assessment, subjects or proxies reported on hospitalizations that occurred throughout the prior year, both at CPMC and elsewhere. For subjects whose admission dates preceded the interview date, we compared self- or proxy-reported CPMC hospitalizations to CPMC admission records. We also examined reports of admissions to other hospitals in the region (Harlem Hospital Center, Montefiore, St. Luke's-Roosevelt, Mt. Sinai, and Bronx VA). Using these data, we examined the proportion of hospitalizations that occurred at CPMC and whether subjects with AD differed from unaffected subjects in the likelihood of a CPMC hospitalization.

Assessment of medical comorbidities.—A subset of WHICAP subjects received a medical examination by research team physicians as part of their follow-up. For these patients, physicians conducted exams, inspected medications, and interviewed patients and proxies about medical conditions. Physicians recorded the presence or absence of 12 medical conditions (myocardial infarct/ischemic heart disease, congestive heart failure, peripheral vascular disease, cerebrovascular disease, dementia, chronic obstructive pulmonary disease, peptic ulcer, liver disease, diabetes, renal disease, and systemic malignancy).

A modified comorbidity index was calculated following Charlson's recommendations (14). The Charlson index weights comorbid conditions by the strength of their association with mortality; a weighted sum is then calculated. Following this approach, chronic liver disease, chronic obstructive pulmonary disease, gastrointestinal disease, myocardial infarction, diabetes, peripheral vascular disease, stroke, arthritis, and hypertension were all assigned a weight of 1; chronic renal disease and systemic malignancy were assigned a weight of 2. Subjects were then categorized according to the following scores: 0 (no comorbid condition), 1 (one comorbid condition), 2 (two comorbid conditions or one of the more severe conditions), 3+ (three or more conditions, or at least one severe condition with another condition). For this measure we used subjects' last medical examination, which was available for 1,034 subjects.

Information on psychiatric comorbidity was also collected for subjects meeting criteria for AD. For this assessment, subjects' proxies completed the Columbia University Scale for Psychopathology in Alzheimer's Disease (CUSPAD), which records the presence of psychiatric symptoms common in AD patients (15).

Analyses

Total hospital use and CPMC admissions.—WHICAP subjects and proxies were asked to report all hospital use and site(s) of hospitalization. We calculated the proportion of total hospital use accounted for by CPMC admissions and whether subjects with AD differed from unaffected subjects in the likelihood of a CPMC admission.

Comparison of medical record admissions to interview-reported admissions.—Subject and proxy reports of CPMC hospitalization were cross-classified with electronic hospital admission data. The sensitivity and specificity of reported admissions were calculated using the electronic medical record as the criterion.

Rates of CPMC admission.—The proportion of subjects with a CPMC medical record admission over the reporting period was calculated for unaffected subjects, subjects with mild or moderate AD, and subjects with severe AD. In addition, other predictors of hospital admission were examined, including sociodemographic status (gender, age, education, race-ethnicity), number of comorbid medical conditions (modified Charlson index), and whether subjects died during the reporting period. The last is an important predictor because a large proportion of hospital care involves end-of-life care (16). Multivariate logistic models were developed to examine predictors of hospitalization and to determine if AD diagnosis was a significant, independent predictor of hospitalization, controlling for these other factors.

Features of AD potentially associated with hospitalization.—Because psychiatric morbidity is a feature of AD and may also be a cause of hospitalization, AD subjects who were hospitalized in the reporting period were compared to those who were not to determine if levels of psychiatric symptoms differed. Discharge diagnoses of AD and non-AD patients were also compared to determine if subjects with AD were hospitalized for different conditions than elders without AD.

RESULTS

Total hospital use and CPMC admissions.—In the WHICAP cohort, 263 of the 2,003 subjects (13.1%) were admitted to

CPMC, as documented by the electronic reporting system, over the 21-month reporting period. Number of admissions among these subjects ranged from 1 to 11, but 61.6% had a single admission over this period.

Total length of stay, summated, when necessary, over repeated admissions, ranged from 1 to 158 days. Median total length of stay was 8 days.

Information obtained from subject interviews suggests that the CPMC electronic records system captured the majority of hospitalizations in the cohort. Of the 1,145 subjects completing an in-person interview in 1996–97, 20.1% reported at least one hospitalization and 63% of these were reported as CPMC admissions. AD and non-AD WHICAP subjects (or proxies) were equally likely to report CPMC as the site of hospitalization (71% and 61% of reported hospitalizations, respectively, $p = .20$).

Comparison of medical record admissions to interview-reported admissions.—Comparing interview-reported CPMC admissions to admissions documented in the electronic records system showed that the sensitivity of interview reports was 69.8% and specificity was 92.5%.

Rates of CPMC admission.—Characteristics of subjects who had a medical record-documented CPMC admission over the reporting period are shown in Table 1.

Men and women were equally likely to have a hospitalization (13.5% of males in the cohort were hospitalized, compared to 12.9% of females, $p = .74$). Risk of hospitalization increased with age, ranging from 11.7% among those younger than 70 to 17.9% among those 85 and older; however, this relationship did not achieve statistical significance ($p = .11$). Risk of hospitalization also did not differ among ethnic-racial groups: 12.1% of the whites, 11.4% of the African Americans, and 14.7% of the Hispanics had a CPMC admission during this period. By contrast, level of education was a significant predictor of hospitalization. Of the WHICAP subjects who had completed high school, 10.4% had a CPMC hospitalization in the reporting period, compared to 15.8% and 16.0% among subjects whose education did not go beyond elementary school ($p < .03$).

Of the 2,003 WHICAP subjects alive at the beginning of the electronic medical record monitoring period, 99 (4.9%) were residing in nursing homes. CPMC hospitalization rates, as indicated by the electronic medical record, were higher among these subjects (17.2%) than among non-nursing home subjects (12.9%), but this difference did not achieve statistical significance ($p = .22$).

Comorbid conditions were strongly associated with risk of hospitalization: 8.9% of subjects with no comorbid conditions at their last assessment were hospitalized, compared to 18.1% among subjects with a Charlson score of 1, 19.7% among subjects with a score of 2, and 25.1% among subjects with scores of 3 or more on the index ($p < .0001$).

AD was also associated with a significant increase in the risk of hospitalization over the reporting period. Of subjects with AD, 17.5% were hospitalized, compared to 11.9% of subjects without AD ($p < .01$). This risk increased with severity of AD, as indexed by CDR scale score. While 11.9% of subjects without AD had a CPMC admission, the risk was 15.9% for subjects with dementia of mild or moderate severity (odds ratio [OR] 1.4, 95% confidence interval [CI]: 1.0, 1.9) and 26.4% for subjects with advanced dementia (OR 2.7, 95% CI: 1.5, 4.6).

Finally, the subjects who died in the reporting period (2.8%) were also more likely to have had a CPMC admission reported in the electronic records system. Of the subjects who died, 21.4% had been admitted to CPMC in the 21 months of the reporting period, compared to 12.8% of those who did not die in this period ($p = .06$). Subjects with AD were also more likely to die in this period than subjects who did not meet criteria for AD (5.4% vs 2.1%, $p < .001$).

Multivariate analyses of hospitalization.—Multivariate logistic regression models showed that more advanced AD was a significant risk factor for hospitalization independent of sociodemographic factors, comorbid medical status, and death in the reporting period. This finding is shown in Table 2, which presents two models, one without comorbid medical status as a predictor ($n = 1978$) and one including this predictor ($n = 993$), because of the different sample sizes used in constructing the two models.

In both models, severe AD was an independent predictor of hospitalization (Model 1: OR 2.3; 95% CI: 1.3, 4.0; Model 2: OR 2.3, 95% CI: 1.1, 4.6). In neither model was mild-moderate AD

Table 1. Features of WHICAP Cohort by Hospitalization Status

Predictor (n)	Hospital Admission (%)	p value*
Gender		
Female (1,424)	12.9	
Male (579)	13.5	.74
Age (yr)		
<70 (433)	11.7	
71–74 (515)	11.8	
75–79 (287)	13.3	
80–84 (214)	13.0	
>85 (149)	17.9	.11
Residence		
Community (1,904)	12.9	
Nursing home (99)	17.2	.22
Race-Ethnicity		
White (397)	12.1	
African American (674)	11.4	
Hispanic (916)	14.7	.12
Education (yr)		
0–3 (368)	16.0	
4–6 (387)	15.8	
7–9 (442)	13.3	
10–12 (502)	10.4	
13+ (282)	10.3	.03
Charlson Index (Comorbidities)		
0 (369)	8.9	
1 (282)	18.1	
2 (183)	19.7	
3+ (171)	25.1	<.0001
Alzheimer's Disease Diagnosis		
Normal (1,603)	11.9	
Mild-moderate AD (328)	16.4	
Severe AD (72)	26.4	<.001
Death in Reporting Period		
No (1,947)	12.8	
Yes (56)	21.4	.06

*Significance test by χ^2 or one-way analysis of variance.

significantly associated with hospitalization. Higher scores on the comobidity index were also significantly associated with risk of hospitalization, and low education remained a significant predictor even with inclusion of comorbid medical status in the model.

Number of hospitalizations and hospital length of stay.—For people with documented admissions to CPMC, we examined number of hospitalizations and total length of stay by AD status and scores on the comorbidity index. While AD severity predicted risk of hospitalization, severity was not significantly associated with number of hospitalizations or length of stay. Both AD and non-AD patients with CPMC admissions averaged about two admissions. Likewise, length of stay across these admissions did not significantly differ. Subjects without AD spent a mean of 17.6 days in the hospital, compared to 14.4 days among patients with mild-moderate AD, and 14.9 days among patients with severe AD.

By contrast, comorbid medical status was strongly associated with number of admissions and length of stay among subjects hospitalized in the reporting period. For these subjects, the number of admissions was 1.3 among subjects with no comorbidities, 1.7 for subjects with scores of 1, 2.0 for subjects with scores of 2, and 2.6 for subjects with scores of 3 or more on the modified Charlson index ($p < .01$). Similarly, total length of stay was 10.3, 14.3, 20.8, and 25.2 days, respectively, according to Charlson score ($p < .03$).

Table 2. Predictors of Hospitalization: Multivariate Logistic Regression

Predictor	Model 1 (n = 1978) OR (95% CI)		Model 2 (n = 1034) OR (95% CI)	
Gender				
Male (reference)	1.0	—	1.0	—
Female	0.9	(0.7, 1.2)	0.9	(0.6, 1.4)
Age (yr)				
≤70 (reference)	1.0	—	1.0	—
71–74	1.0	(0.7, 1.5)	0.9	(0.6, 1.6)
75–78	1.1	(0.7, 1.6)	0.9	(0.5, 1.6)
79–84	1.1	(0.7, 1.7)	0.9	(0.5, 1.7)
>85	1.4	(1.0, 2.5)	1.1	(0.6, 2.0)
Education (yr)				
0–3	1.6	(1.0, 2.5)	2.0	(1.0, 4.1)
4–6	1.5	(0.8, 2.1)	2.4	(1.1, 4.8)
7–9	1.3	(0.6, 1.6)	2.0	(1.0, 4.0)
10–12	1.0	(0.7, 1.6)	1.2	(0.6, 2.3)
13+ (reference)	1.0	—	1.0	—
Death				
Alive (reference)	1.0	—	1.0	—
Dead in reporting period	1.7	(0.9, 3.4)	1.6	(0.7, 3.6)
Alzheimer's Disease Diagnosis				
Normal (reference)	1.0	—	1.0	—
Mild-moderate AD	1.1	(0.7, 1.6)	1.2	(0.7, 1.8)
Severe AD	2.3	(1.3, 4.1)	2.3	(1.1, 4.6)
Charlson Index (Comorbidities)				
0 (reference)			1.0	—
1			2.2	(1.4, 3.5)
2			2.5	(1.5, 4.1)
3+			3.1	(1.9, 5.2)

**Note:* OR = odds ratio; CI = confidence interval.

Features of AD relevant for hospitalization.—Discharge diagnoses for AD and non-AD groups were similar except in the case of infectious disease. Of subjects with AD who were hospitalized, 40.8% had pneumonia or other infectious disease as their coded discharge diagnosis, compared to 27.2% among subjects not meeting criteria for AD ($p < .05$).

Psychiatric morbidity, a common feature of AD, was also examined as a cause of the increased likelihood of hospital admissions among subjects with AD. However, hospitalized elders with AD did not show a significantly higher prevalence of psychiatric symptoms or behavioral agitation than elders with AD who were not hospitalized (25.5% vs 20.0%, respectively, $p = .29$).

Finally, we examined hospital use among AD and non-AD subjects who died in the follow-up period. Among subjects who died in the reporting period, subjects with AD were more likely to have been hospitalized than subjects without AD. Seven out of 22 (31.8%) of AD subjects who died were hospitalized in the reporting period, compared to 5 out of 34 (14.7%) of non-AD subjects who died ($p < .01$). The time between first hospitalization and death ranged from 13 to 368 days and did not significantly differ between AD and non-AD subjects.

Discussion

This community-based study shows that elders meeting criteria for AD face an increased risk of hospitalization relative to cognitively normal elders; 17.5% of subjects with AD were hospitalized at Columbia-Presbyterian Medical Center over 21 months, compared to only 11.9% of subjects without AD. These rates do not account for all hospitalizations, but only those occurring at CPMC. Data collected during the concurrent survey suggest that these hospitalizations account for about two thirds of all subjects who were hospitalized (71% of AD subjects, 61% of non-AD subjects). We can therefore impute total hospital use. With such an imputation, the annual risk of hospitalization was 11.1% among non-AD patients, 14.1% among all AD patients, and 21.2% for subjects with severe AD, as defined by a CDR score of 3+.

The elevated risk of hospitalization associated with more advanced dementia was independent of other factors associated with hospitalization, such as age, education, comorbid conditions, and subsequent mortality. The increased risk, therefore, appears to be specific to advanced AD, although not explained by the psychiatric morbidity typical of the disease or the increased risk of death associated with AD. AD patients admitted to CPMC and AD patients without an admission were equally likely to have psychiatric symptoms, and severe AD was significantly associated with hospitalization even when controlling for death in the follow-up period.

AD patients who were hospitalized differed from non-AD patients hospitalized in the same period (and at the same hospital) in only one discharge diagnosis, infectious disease (40.8% vs 27.2%), as coded by physicians who inspected discharge diagnoses. Therefore, we conclude that at least part of the excess risk of hospitalization associated with AD is likely due to an increased risk of infection—in particular, pneumonia, requiring hospital treatment. It is possible, however, that infections coded on the discharge diagnosis may also have had a nosocomial origin. We are currently investigating this issue.

An important feature of this community-based study is its use of hospital admissions records, rather than self- or proxy re-

ports, in a geographic area where a single hospital is the major source of hospital care. The proportion of AD and non-AD subjects (or proxies) in Washington Heights-Inwood who reported CPMC as the site of hospital admission in a concurrent interview did not significantly differ. Thus, it appears that the two groups were equally likely to use CPMC for hospital care. Another important aspect of the study is its use of actual diagnoses of AD based on a full battery of neuropsychological tests and neurologic examination. Prior population-based studies have relied, for the most part, on screening tests to identify older adults with cognitive impairment (2,3). Other studies have addressed the risk of hospitalization among AD patients but relied on patients drawn from AD registries or research centers and did not include information on rates of hospitalization among elders without AD (5).

The most relevant study for comparison is the Monongahela Valley Independent Elders Survey, which is population-based and which included hospitalization as an outcome (3). However, the Monongahela Valley study did not diagnose AD but rather defined "cognitive impairment" empirically. Cognitive impairment was defined as a score below the 5th percentile of the sample distribution for the Mini-Mental State Examination or for two other cognitive tests, including one test of memory. By this standard, Ganguli and colleagues (3) found that 19.1% of cognitively impaired elders were hospitalized over a 6-month period, compared to 10.2% of unimpaired elders. These rates were based upon subject or proxy reports of hospital use, and the greater risk for hospitalization among cognitively impaired elders was no longer significant in multivariate models. In the WHICAP cohort, by contrast, advanced AD remained a significant risk factor for hospitalization in multivariate models that included sociodemographic factors, comorbid conditions, and death during the follow-up period.

Despite the increased risk of hospitalization associated with advanced AD in the WHICAP cohort, we did not find an increased length of stay or increased number of admissions when we limited analyses to patients who had been admitted to the hospital. This contrasts with findings reported by Weiler and colleagues (2), who reported that "moderate/severe" cognitive impairment was associated with an increased risk of longer hospital stays in the late 1980s. Perhaps because of changing trends in hospital care, severely affected AD patients in WHICAP were more likely to be hospitalized but not more likely to have longer length of stays once admitted.

Our results suggest that severe AD is a significant, independent risk factor for hospitalization. For severe AD, then, we do not find evidence that aggressive care, at least as it is indexed by hospital admissions, is limited. This finding supports research reported by Fried and Gillick (6). They found that family caregivers were likely to limit aggressive care for elders with terminal disease and for elders in institutional settings, but found no such limitation for elders with dementia living in community settings.

We conclude that the "malignancy" of AD (17) includes not simply greater risk of death, but also greater risk of medical complications, especially infections, that require hospital care.

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