Inappropriate Medication Use and Health Outcomes in the Elderly

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Inappropriate medication use is a major problem for the elderly. Although increasing attention has been paid to inappropriate prescription medication use, most previous research has been limited to the investigation of prevalence and trends. Few studies provide the empirical evidence for the adverse effect of inappropriate medication use on health outcomes at the national level. This study is the first attempt to assess the relationship between inappropriate prescription use and health status for the elderly in the United States.

Based on the 1996 Medical Expenditure Panel Survey, inappropriate medication use in a national representative elderly population was first identified using Beers criteria. A survey type of ordered probit model was then estimated to quantify the effect of inappropriate drug use on patient self-perceived health status measured using a five-point scale (poor, fair, good, very good, and excellent). After controlling for a set of possible confounding factors, it was found that individuals using inappropriate medications in Round 1 were more likely than those not using inappropriate medications to report poorer health status in Round 2. Other risk factors for poor health status include a higher number of prescriptions, being black, having low education, and having one or more chronic diseases.

This study provides strong evidence of a significant adverse effect of inappropriate medication use on patient health status. These findings lend partial support to the use of Beers criteria in assessing the quality of prescribing and the appropriateness of medication use in the elderly population. J Am Geriatr Soc 52:1934–1939, 2004.

Key words: inappropriate prescribing; Beers criteria; MEPS; health status; ordered probit model
study is intended to help fill the gap by quantifying the possible adverse effect of inappropriate drug use on patient perceived health outcomes by estimating a set of health status models in relation to inappropriate drug use in the elderly using the national Medical Expenditure Panel Survey (MEPS).

METHODS

Data Source
Data were extracted from the 1996 MEPS data set, which provides nationally representative estimates of healthcare utilization, expenditures, sources of payment, and insurance coverage for the noninstitutionalized population. MEPS, maintained by the Agency for Healthcare Research and Quality, uses an overlapping panel design in which data are collected through preliminary contact followed by a series of five rounds of interviews per panel with a time lag of 4 to 5 months for about 2 years.

This study used the Round 1 and 2 information within the household component of the 1996 MEPS, initially released in 2000. This data set contains records for 22,601 persons, including a person-level weight variable that allows making estimates for the noninstitutionalized U.S. population for 1996. There are also 147,308 prescribed medicine records in the data set. Each record represents one household-reported prescribed medicine that was purchased or obtained during 1996, and each record contains medical conditions associated with the prescribed medicine. The population studied was people aged 65 and older.

Analytical Approaches

Outcomes Variable
The primary outcomes variable was self-perceived health status. In MEPS, respondents were asked to rate their health status compared with other persons of their age as excellent, very good, good, fair, or poor. This self-assessment approach has been widely used as a means of gathering information on health status in epidemiological research and has proven to have substantial reliability and predictive validity.21

Explanatory Variables
In the health outcomes model, the key intervention variable is whether an individual used any inappropriate prescribed drugs. Inappropriate drug use was defined as exposure to any drug on the updated Beers list of 26 drugs or categories of drugs.14 Because MEPS lacks information on daily dosage or frequency of use for every prescription, only 23 criteria were included in the analysis. Three of the drug categories (benzodiazepines, digoxin, and iron supplements) were not included in the analysis because they are only considered inappropriate beyond certain daily dose.

In addition to inappropriate prescription use, three sets of variables are assumed in the model to affect an individual's health status. The first set, referring as predisposing variables, comprises age, sex, race, education, employment status, and marital status.22

The second set comprises enabling variables such as income, census region, Metropolitan Statistical Areas, and health insurance. Because the entire sample was eligible for Medicare, health insurance was categorized into four groups: Medicare only, Medicare with some private insurance, Medicare with other public insurance including Medicaid, and Medicare with private and other public insurance.

The third set of variables was intended to control for health conditions that can determine a person's current health status. To minimize a possible endogeneity problem with health conditions in the outcomes model, Round 1 disease condition and functional limitation variables were used as additional variables to control for preperiod health status. Based on International Classification of Diseases, Ninth Revision, Clinical Modification codes, nine chronic disease conditions were included: heart disease, hypertension, lung disease, cancer, stroke, diabetes mellitus, more than one of these diseases, other diseases, and no diseases. Functional condition variables included help needed in activities of daily living, help needed in instrumental activities of daily living, assistant devices used, limitations in physical functioning, work/housework/school limitation, social limitations, and cognitive limitations.

Econometric Modeling

Because of the five-scale ordinal nature of the health status variable, the ordered probit model was employed to estimate the discrete outcome function.23 A reduced form of the outcome function can be written as follows:

\[
\Pr(H_{i2}) = \Phi(x + \beta \cdot M_{i1} + \delta_1 \cdot N_{i1} + \delta_2 \cdot H_{i1} + \delta_3 \cdot Z_{i2} + \epsilon_i)
\]

where \(H_{i2}\) is the health status for individual \(i\) in Round 2; \(M_{i1}\) is a vector indicating the status of inappropriate drug use for individual \(i\) in Round 1; \(N_{i1}\) represents the total number of prescription drugs for individual \(i\) in Round 1; \(H_{i1}\) is a vector consisting of Round 1 health conditions as need variables, including preexisting health status and health conditions; \(Z_{i2}\) is a vector controlling for other observed factors that are in the categories of predisposing and enabling variables as noted earlier; \(\epsilon_i\) is a random error term to capture all unobserved factors; and \(\Phi\) represents the probit cumulative distribution function.

It is worth noting that the model was specified to include medication use pattern in Round 1 as a key intervention variable to influence health status in Round 2. Conceptually, inappropriate use of a drug could have a short-run and long-run effect on one's health status. If employing the Round 2 medication use pattern in the model, a potential endogeneity problem would occur. This is because individuals with poor health status may need more medications and thus became more likely to encounter an inappropriate medication, all other factors being equal.17 Alternatively, the link between drug use in Round 1 and health status in Round 2 was sought, with a presumption that one's medication use pattern in Round 1 and 2 would be correlated. This presumption was supported by the empirical test results, suggesting a high correlation between the medication use variables in the two rounds.

In estimating the model, the complex sample design of MEPS was taken into account, featuring stratification, clustering, multiple stages of selection, and disproportionate sampling. This results in serious departures from simple random sampling assumptions. To obtain valid estimates of
the standard errors for the model, the design complexities were taken into account by specifying the variance estimation strata and the variance estimation primary sample units in a survey type of ordered probit model. Data coding and econometric modeling were conducted using SAS version 8 (SAS Institute, Inc., Cary, NC) and Stata version 6 (Stata Corp., College Station, TX), respectively.

RESULTS

Descriptive Statistics

After excluding observations with missing variables, the final sample derived from the 1996 MEPS included 2,305 elderly, representing 30,485,173 elderly nationwide, with weight adjustment. Of the original sample in Round 1, there were 537 nonusers of any prescription drugs, 1,462 appropriate medicine users, and 306 inappropriate medicine users. (Number of inappropriate prescriptions ranged from 1 to 12, with mean 2.2 and median 2.) The most frequently inappropriately used drugs were propoxyphene and those containing propoxyphene. In Round 1, the distribution of perceived health status was excellent, 19.1%; very good, 25.7%; good, 28.7%; fair, 18.5%; and poor, 8.0%. Similarly, in Round 2, the distribution was excellent, 18.4%; very good, 26.7%; good, 28.0%; fair, 18.7%; and poor, 8.3%. Chi-square ($\chi^2$) test results confirmed that there was no difference between the two distributions ($\chi^2 (4) = 1.036, P = .85$).

Elderly persons who used inappropriate prescriptions in Round 1 were more likely than those who did not to perceive fair or poor health status in Round 2. Chi-square test indicated that the postperiod health status was significantly associated with inappropriate prescription drug use in the preperiod ($P < .001$).

Modeling Strategies

In an effort to minimize the effect of potential confounding factors, a sequential modeling strategy was employed by adding one additional group of explanatory variables at a time in specifying the models. Model A in Table 1 reports the ordered probit model results when the equation included only prescription drug use. The inappropriate drug use group had significantly worse health status and the nonuse group had significantly better health status, both compared with the group with appropriate drug use.

Models B to D sequentially added in additional control variables. After including the total number of prescriptions in Model B, the coefficient of inappropriate drug use decreased substantially (from $-0.517$ to $-0.330$) toward the null, indicating the strong confounding effect of the total number of prescriptions taken. Adding predisposing and enabling variables in Model C, the coefficient remained virtually the same as before, indicating that these two sets of variables would not confound or modify the estimates. However, after adding the need variables in Models D to F, the coefficient of inappropriate drug use decreased steadily, strongly suggesting that the need variables would otherwise bias the estimates upward if not controlled. This is consistent with the hypothesis that no difference in health status would exist between the elderly with appropriate medication use and those without any medication use after controlling for preexisting health conditions.

Compared with Model D, Model E replaced the Round 1 health status with health-condition variables. The decrease in the coefficient of interest (from $-0.284$ to $-0.235$) implies that health condition variables are more likely to control for the underlying confounding problem and therefore help minimize the endogeneity. The full Model F adds in the prior health-status and health-condition variables. The coefficient of inappropriate prescription drug use becomes more stabilized at $-0.235$ to $-0.234$ across the different model specifications, suggesting the relative robustness and reliability of the full Model F. In specifying the full model, there was a concern about multicollinearity within the right-hand side variables in the model. Accordingly, a pair-wise correlation analysis was performed, which confirmed that multicollinearity is not a problem for the study results. Thus the full model results are reported in the following sections (Table 2).

Explanatory Results

Compared with those with appropriate prescription drug use, the elderly with inappropriate drug use in Round 1 reported significantly worse health status in Round 2 ($P < .01$). The total number of prescriptions was strongly associated with poorer health status ($P < .01$). As for the predisposing variables, older blacks had significantly poorer health status than whites ($P < .05$). Elderly with higher educational degree had better health status than those with less education ($P < .05$). Of the enabling variables, none was found to be predictive of health status, including health insurance.

As expected, need variables were most highly correlated with perceived health status. Round 1 health status was

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**Table 1. Effect of Inappropriate Prescription Use on Health Status**

<table>
<thead>
<tr>
<th>Prescription Drug Use</th>
<th>Model</th>
<th>Coefficient ± Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A</td>
<td>B</td>
</tr>
<tr>
<td>Inappropriate</td>
<td>$-0.517 ± 0.082^*$</td>
<td>$-0.330 ± 0.088^*$</td>
</tr>
<tr>
<td>No use</td>
<td>$0.508 ± 0.062^*$</td>
<td>$0.237 ± 0.068^*$</td>
</tr>
</tbody>
</table>

Note: Appropriate drug use is the reference group. Control variables were total number of prescriptions for Models B, C, D, E, and F; predisposing and enabling variables for Models C, D, E, and F; self-perceived health status for Models D and F; and health condition variables for Models E and F.

*$P < .01$; $^*P < .001$. 

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highly predictive of Round 2 health status, with a decreasing trend in magnitude of the coefficients from excellent to fair, relative to people with poor health status ($P < .001$). Likewise, disease condition variables were strongly predictive of health status. Elderly patients with heart disease ($P < .01$), hypertension ($P < .001$), lung disease ($P < .05$), diabetes mellitus ($P < .001$), more than one of the mentioned diseases ($P < .001$), or any other disease conditions ($P < .01$) in Round 1 were much more likely to report poorer health than those free of any chronic conditions. Moreover, poorer health was shown to be associated with having limitations in physical ($P < .001$) and cognitive ($P < .01$) function.

The effect of inappropriate drug use on health status based on the estimated coefficient of $-0.234$ in Table 2 will now be focused on. Because ordered probit model does not allow a straightforward interpretation of its coefficients as linear models do, the following simulation procedures were undertaken. Holding all controlled variables in the model at their actual value for each individual, the probability of having each health status was predicted while varying the dummy value of inappropriate prescription use. These

### Table 2. Ordered Probit Model of Health Status for the Elderly

<table>
<thead>
<tr>
<th>Variable*</th>
<th>Coefficient</th>
<th>SE</th>
<th>t</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary interested</td>
<td>Prescription drug use</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inappropriate</td>
<td>$-0.234$</td>
<td>$0.084$</td>
<td>$-2.78$</td>
<td>$.006$</td>
</tr>
<tr>
<td>No use</td>
<td>$-0.085$</td>
<td>$0.097$</td>
<td>$-0.88$</td>
<td>$.38$</td>
</tr>
<tr>
<td>Appropriate (Reference)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total number of prescriptions</td>
<td>$-0.013$</td>
<td>$0.005$</td>
<td>$-2.58$</td>
<td>$.01$</td>
</tr>
<tr>
<td>Predisposing</td>
<td>Race (reference: white)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>$-0.238$</td>
<td>$0.097$</td>
<td>$-2.47$</td>
<td>$.014$</td>
</tr>
<tr>
<td>Other race$^\dagger$</td>
<td>$0.508$</td>
<td>$0.213$</td>
<td>$2.39$</td>
<td>$.017$</td>
</tr>
<tr>
<td>Higher degree of education (reference: no degree)</td>
<td>$0.220$</td>
<td>$0.096$</td>
<td>$2.28$</td>
<td>$.023$</td>
</tr>
<tr>
<td>Need</td>
<td>Self-perceived health status (reference: poor)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Excellent</td>
<td>$2.861$</td>
<td>$0.172$</td>
<td>$16.62$</td>
<td>$&lt; .001$</td>
</tr>
<tr>
<td>Very good</td>
<td>$2.046$</td>
<td>$0.137$</td>
<td>$14.97$</td>
<td>$&lt; .001$</td>
</tr>
<tr>
<td>Good</td>
<td>$1.455$</td>
<td>$0.126$</td>
<td>$11.52$</td>
<td>$&lt; .001$</td>
</tr>
<tr>
<td>Fair</td>
<td>$0.881$</td>
<td>$0.125$</td>
<td>$7.05$</td>
<td>$&lt; .001$</td>
</tr>
<tr>
<td>Disease condition (reference: no disease condition)</td>
<td>Heart disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertension</td>
<td>$-0.406$</td>
<td>$0.123$</td>
<td>$-3.29$</td>
<td>$.001$</td>
</tr>
<tr>
<td>Lung disease</td>
<td>$-0.382$</td>
<td>$0.168$</td>
<td>$-2.27$</td>
<td>$.02$</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>$-0.454$</td>
<td>$0.174$</td>
<td>$-2.61$</td>
<td>$.009$</td>
</tr>
<tr>
<td>More than one of the above disease</td>
<td>$-0.607$</td>
<td>$0.136$</td>
<td>$-4.46$</td>
<td>$&lt; .001$</td>
</tr>
<tr>
<td>Other diseases except the above</td>
<td>$-0.302$</td>
<td>$0.109$</td>
<td>$-2.76$</td>
<td>$.006$</td>
</tr>
<tr>
<td>Functional and activity limitations</td>
<td>Limitation in physical functioning</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cognitive limitations</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The model was estimated using the 1996 MEPS data with 135 strata, 537 clusters, 2,305 of observations, and the sum of national weights equal to 30,485,175. *Only variables (variable groups) with significant coefficients are listed. Variables included in the model but excluded from the table include age, sex, general equivalency diploma, high school, other degree, employment status, marital status, income, census region, metropolitan statistical areas, health insurance, stroke, cancer, activities of daily living help, instrumental activities of daily living help, assistance devices used, work/housework/school limitation, social limitation. Details about the statistics are available upon request from the authors. $^\dagger$ American Indian, Aleut, Eskimo, Asian or Pacific Islander.

### Table 3. Distribution of Health Status in Round 2 by the Use of Prescriptions in Round 1

<table>
<thead>
<tr>
<th>Round 1 Prescription Use</th>
<th>Round 2 Health Status</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Excellent</td>
</tr>
<tr>
<td>Inappropriate</td>
<td>$15.9 \pm 0.50$</td>
</tr>
<tr>
<td>Appropriate</td>
<td>$18.7 \pm 0.52$</td>
</tr>
<tr>
<td>Difference</td>
<td>$-2.8 \pm 0.07$</td>
</tr>
</tbody>
</table>
DISCUSSION
Although previous studies suggested a widely believed notion that inappropriate drug use would have adverse effects on patient health outcomes, especially in the elderly, this study adds to the literature by providing the first empirical evidence documenting such an effect for the national elderly population derived from the 1996 MEPS data. After controlling for a number of confounding factors in the model, this study found strong evidence of a sizable and consistent negative effect of inappropriate prescription drug use on patient health status.

A few other findings are noteworthy. Among the predisposing variables, there was a significant racial disparity in health status, in that African Americans had poorer health status than their white counterparts. Previous literature has suggested that African Americans have higher rates of heart disease, stroke, most cancers, pneumonia, influenza, chronic liver disease, and diabetes mellitus than whites.25,26 Given these findings, it is not surprising that this study found a similar pattern of racial disparity in self-perceived health status. It was also found that higher education was associated with better health status. This finding is consistent with the well-known notion that education and health, the two most important elements of human capital, are mutually enhanced in the household production process,27–29 but healthier people tend to invest more in education in an attempt to recoup more returns from the investment. Better-educated people in return are likely to be more productive and efficient in maintaining health and using healthcare resources.

The model showed little dependence of health status on enabling variables, including income, insurance type, and regional settings. It could be the case that none of the variables played a substantial role in determining health status, but it cannot be excluded that the insignificant relationships were partly attributed to measurement errors of the variables in the database. Poor measurement leads to attenuation bias, but it is also possible that patients who were prescribed inappropriate medications would receive medical care below acceptable standards or quality, which could negatively affect self-perceived health. This possible effect could not be controlled for in the model because of data limitation.

As expected, need variables were the most predictive of health status outcomes. Round 1 health status was most highly correlated with Round 2 health status, following a decreasing trend of the quantitative coefficients from excellent to fair, but to some extent, this variable is subject to an endogeneity bias, as discussed earlier. In contrast, health-condition variables, including chronic disease conditions and functional activity limitations, were deemed to be more objective in measuring need for care and less endogenous in the determination of self-perceived health status. Other unobservables associated with the preperiod health status in the error term could potentially bias the estimate, but a consistent set of coefficients was obtained across all the model specifications to indicate the strong effect of a chronic condition on self-perceived health status. Therefore, the potential bias due to unobservables does not seem to be a major concern. Although it is difficult to fully eliminate the estimation bias, the sequential modeling strategy seemed to help reach the robustness of the estimates as the coefficient of inappropriate drug use converges to a stable value.

In addition, MEPS does not provide information on daily dosage or frequency of use for every prescription. As a result, some drugs had to be excluded from the model because of conditional appropriateness. In particular, benzodiazepines, digoxin, and iron supplements were not included in the analysis because they would be inappropriate only when their dosage exceeded a certain amount. This limitation would lead to the underestimation of the population size of inappropriate prescription drug use, but because of the low severity of violating these criteria, the expected outcome may not be sensitive to such limitation.14

CONCLUSION
This study is the first empirical research on inappropriate prescription drug use and health outcomes in the elderly based on a nationally representative population sample. Strong evidence was obtained indicating that inappropriate drug use is associated with subsequent decrease in self-perceived health status in the elderly. These results lend partial support to the Beers criteria as valid proxy indicators of poor prescribing practices leading to deterioration of health status. Owing to the national representation design of MEPS, the results can be generalized to the national elderly population in the United States. Previous research suggested that inappropriate drug use would cause an increased use of healthcare resources. The current study provides an important addition to the literature suggesting that inappropriate drug use also can have sizable adverse effects on patient health outcomes. Together, these studies suggest that inappropriate prescription drug use can be costly in healthcare resources and health outcomes. Future research can be directed to better address why and how inappropriate medication use can lead to poor outcomes. With such important knowledge, better policy actions can be taken to reduce system medical errors and improve the quality of health care for the elderly.30

REFERENCES
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