Fragmented Ambulatory Care and Subsequent Healthcare Utilization Among Medicare Beneficiaries

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ABSTRACT

OBJECTIVES: We sought to determine the associations between fragmented ambulatory care and subsequent emergency department (ED) visits and hospital admissions, while considering possible interactions between fragmentation and number of chronic conditions.

STUDY DESIGN: We conducted a cohort study over 3 years among 117,977 fee-for-service Medicare beneficiaries who were attributed to primary care physicians in a 7-county region of New York and had 4 or more ambulatory visits in the baseline year.

METHODS: We calculated fragmentation scores using a modified Bice-Boxerman Index and, because scores were skewed, divided them into quintiles. We used Cox regression models to determine associations between fragmentation and ED visits and, separately, hospital admissions, stratifying by number of chronic conditions and adjusting for age, gender, number of ambulatory visits, and case mix.

RESULTS: Among those with 1 to 2 or 3 to 4 chronic conditions, having the most (vs the least) fragmented care significantly increased the hazard of an ED visit and, separately, increased the hazard of an admission (adjusted P <.05 for each comparison). Among those with 5 or more chronic conditions, having the most fragmented care significantly increased the hazard of an ED visit but decreased the hazard of an admission (adjusted P <.05 for each comparison). Among those with 0 chronic conditions, having fragmented care was not associated with either outcome.

CONCLUSIONS: The relationship between fragmented ambulatory care and subsequent utilization varies with the number of chronic conditions. Beneficiaries with a moderate burden of chronic conditions (1-2 or 3-4) appear to be at highest risk of excess ED visits and admissions due to fragmented care.

Am J Manag Care. 2018;24(9):e278-e284

Patients routinely receive care from multiple ambulatory providers, especially if they have chronic conditions.[1] Receiving care from multiple providers may be appropriate, but it often leads to gaps in communication across providers,[2] which can result in suboptimal care. Previous studies have found that more fragmented care (that is, care spread across many providers with no dominant provider) is associated with more testing, more overuse of procedures, and lower patient satisfaction compared with less fragmented care.[3-5] Prior studies have also found associations between more fragmented care and higher rates of emergency department (ED) visits, higher rates of hospital admissions, and higher costs compared with less fragmented care.[6-8]

However, the association between fragmentation and these outcomes is not yet sufficiently described to enable the design of interventions to address it. For example, fragmentation has typically been measured as a continuous variable, which is appropriate but assumes that the relationship between fragmentation and outcomes is linear,[6,8] which may not be the case; rather, a threshold effect may be present, in which a certain amount of fragmentation increases the risk of an outcome. Also, previous studies have adjusted for the number of chronic conditions or case mix, which is appropriate but may mask the possibility that fragmentation affects patients differently depending on how many chronic conditions they have.[8]

Thus, we sought to determine the associations between care fragmentation in the ambulatory setting and subsequent ED visits and hospital admissions, while considering whether those associations vary with number of chronic conditions.

METHODS

Overview

We conducted a cohort study (2010-2012) of fee-for-service (FFS) Medicare beneficiaries who received care from physicians in the Hudson Valley of New York to determine associations between fragmented ambulatory care and subsequent ED visits and hospital admissions. The Institutional Review Board of Weill Cornell Medicine approved the protocol.

Setting

The Hudson Valley consists of 7 counties immediately north of New York City (Dutchess, Orange, Putnam, Rockland, Sullivan, Ulster, and Westchester). Approximately 85% of the people in this region live in urban or suburban areas.[9,10] Approximately 85% of residents have health insurance, and approximately 10% live at or below the federal poverty level.[9,11] At the time of the study, most healthcare in the region was delivered by physicians in small- and medium-size private practices, using FFS reimbursement from multiple payers.[12]

TAKEAWAY POINTS

Among Medicare beneficiaries, the relationship between fragmented ambulatory care and subsequent healthcare utilization varies with the number of chronic conditions.

- Among those with 1 to 2 or 3 to 4 chronic conditions, having the most (vs the least) fragmented care significantly increased the hazard of an emergency department (ED) visit and, separately, increased the hazard of a hospital admission (adjusted P <.05 for each comparison).
- Among those with 5 or more chronic conditions, having the most fragmented care significantly increased the hazard of an ED visit but decreased the hazard of an admission (adjusted P <.05 for each comparison).
- Among those with 0 chronic conditions, having fragmented care was not associated with either outcome.

Data

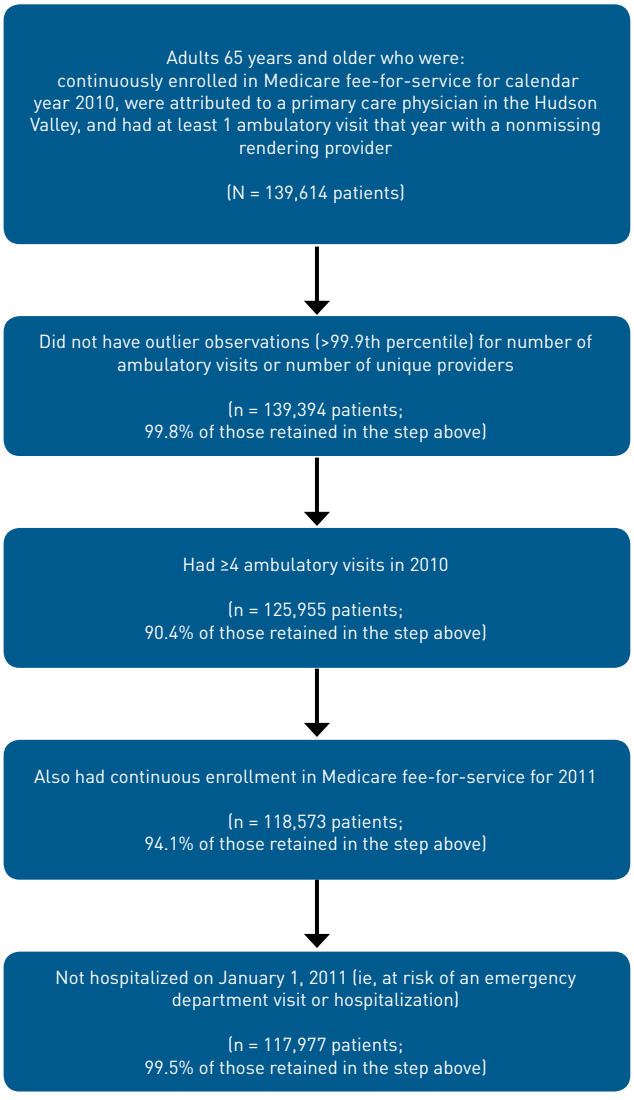
We used Medicare FFS claims data for 2010-2012, extracting the following claim-level variables: patient study identifier (ID), patient date of birth, patient gender, date of service, rendering provider ID, Current Procedural Terminology (CPT) codes, and *International Classification of Diseases, Ninth Revision* (*ICD-9*) codes. We also extracted monthly patient-level enrollment data.

Study Sample

We first identified primary care physicians (general internists and family medicine physicians) in the claims who had billing zip codes in the Hudson Valley (**Figure**). We determined which Medicare beneficiaries 65 years and older could be attributed to those primary care physicians, based on 2010 claims, using previously defined logic.[13] Of those, we identified beneficiaries who were continuously enrolled that year and had 1 or more ambulatory visits. Ambulatory visits were defined by CPT codes, using a modified version of the definition by the National Committee for Quality Assurance (NCQA).[14] Modifications restricted the definition to evaluation-and-management visits for adults in an office setting, excluding management-only visits (eg, physical therapy) and non–office-based visits (eg, visits in nursing homes). This definition also excluded ED visits.

We excluded beneficiaries with outlier observations (>99.9th percentile) for number of ambulatory visits or unique providers, because those observations may have been erroneous. Next, we restricted the cohort to those with 4 or more ambulatory visits in the baseline year, because calculating fragmentation with 3 or fewer ambulatory visits can lead to statistically unstable estimates.[8] We required that beneficiaries be continuously enrolled in Medicare for at least 1 more consecutive year, contributing data for 2 years (2010-2011) or 3 years (2010-2012). Finally, we excluded those who were in the hospital on January 1, 2011, because they were not at risk of an ED visit or hospital admission at the start of follow-up.

FIGURE. Derivation of the Study Sample



Statistical Analysis

Independent variable. Our base-case analysis measured fragmentation with the Bice-Boxerman Index (BBI) (**eAppendix A** [eAppendices

available at **ajmc.com**]),[15,16] a previously validated measure.[3,4,6,8,16] We reversed raw BBI scores, so that higher scores would reflect more fragmentation. Patterns of care that reflect high dispersion (many providers) and low density (a relatively low proportion of ambulatory visits by each provider) yield worse (higher) scores. Because the distribution of BBI scores is inherently skewed, we divided scores into quintiles, an approach we successfully used previously,[3] to maximize clarity of interpretation. We conducted sensitivity analyses with 2 other fragmentation indices, the Herfindahl-Hirschman Index and the Usual Provider Continuity Index (eAppendix A).[16]

Dependent variables. We identified ED visits and hospital admissions in the claims, using definitions from NCQA.[14] An "ED visit" resulted in discharge to home or elsewhere. If an ED visit resulted in hospital admission, it was considered part of that admission and counted only as an admission.

Potential confounders. We used *ICD-9* codes to calculate the number of chronic conditions for each beneficiary (0, 1-2, 3-4, or ≥5)[3] of 26 unique chronic conditions defined by CMS (**eAppendix B**).[17] We also calculated a severity of illness index.[18,19] We considered beneficiary age and gender as potential confounders. In addition, we considered the number of ambulatory visits as a potential confounder, because the number of ambulatory visits was weakly correlated with fragmentation score (Spearman correlation coefficient, 0.22; $P < .0001$).

Descriptive statistics. We characterized beneficiaries in terms of age, gender, and number of chronic conditions. We compared the characteristics of the study sample with those who were excluded using pairwise Wilcoxon rank-sum tests for continuous variables and χ^2 tests for categorical variables.

For the study sample, we calculated descriptive statistics regarding the number of ambulatory visits, number of unique providers, and proportion of ambulatory visits with the most frequently seen provider in the baseline year (overall and stratified by fragmentation quintile). We also determined the proportions of beneficiaries who had 1 or more ED visits and, separately, 1 or more hospital admissions during follow-up.

Statistical models. Because fragmentation can change over time and because the hypothesized consequences of fragmented care may unfold relatively quickly, we used Cox models and treated fragmentation as time-dependent. That is, we first calculated fragmentation in the first 12 months (calendar year 2010) and determined whether the beneficiary had an ED visit in month 13 (January 2011) or not. We then moved this window of observation by 1 month, recalculating the model using fragmentation in months 2 to 13 as a potential predictor of an ED visit in month 14, and so on. If the number of ambulatory visits in any 12-month window fell below 4 (making it difficult to calculate fragmentation scores), we carried forward the last fragmentation score that was based on 4 or more ambulatory visits. We used the same approach in separate models predicting hospital admissions.

For each model, observation continued until an outcome or censoring occurred. For the ED visit models, censoring occurred (1) if a beneficiary was admitted to the hospital (with the reasoning that the beneficiary was not at risk of an ED visit) or (2) at the end of the beneficiary's continuous enrollment. For the hospital admission models, censoring occurred only at the end of the beneficiary's continuous enrollment; any ED visit had no effect on the hospital models, because the beneficiary was still at risk of a hospital admission.

We adjusted for beneficiary gender and for the following time-varying covariates: age, Charlson-Deyo score, and number of ambulatory visits. By adjusting for number of ambulatory visits, we sought to fully tease apart fragmentation (the diffuseness of care) from the volume of ambulatory visits, as we have done previously.[3] We calculated an interaction term for fragmentation category*chronic condition count and then, because this term was statistically significant for at least 1 model, we stratified our analyses by chronic condition count.

To test the appropriateness of the statistical assumptions of our models, we generated weighted plots of Schoenfeld residuals by time and calculated zph tests for nonproportional hazards (which is recommended in situations with time-dependent predictors and/or covariates).[20-22]

We considered P values $<.05$ to be statistically significant. We used SAS version 9.4 (SAS Institute; Cary, North Carolina).

RESULTS

Study Sample

We identified 139,614 adults 65 years or older who were continuously enrolled in Medicare FFS in 2010, were attributed to a primary care physician in the Hudson Valley, and had 1 or more ambulatory visit that year (Figure). The average age of this group was 76.8 (SD = 7.5) years, which is fairly similar to that of Medicare beneficiaries 65 years or older nationally (average [SD] age, 75.1 [7.8] years).[23]

Our sample was composed of the 117,977 (85%) beneficiaries who did not have outlier observations, had 4 or more ambulatory visits, had continuous enrollment for at least 1 more consecutive year, and were not hospitalized on the first day of 2011 (Figure).

Sample Characteristics

Among the 117,977 beneficiaries in our sample, the mean age was 77.2 years (**Table 1**). More than half (60.8%) were women. The distribution of counts of chronic conditions was as follows: 1.4% had 0 chronic conditions, 18.6% had 1 to 2 chronic conditions, 39.1% had 3 to 4, and 41.0% had 5 or more. Most beneficiaries (93%) contributed data for all 3 years of the study, whereas the remainder (7%) contributed data for the first 2 years only.

The 13,439 beneficiaries (10% of the total) who were excluded because they had 3 or fewer ambulatory visits were younger and healthier than those who were included (**eAppendix C**). The 7978 beneficiaries (6% of the total) who were excluded because they were not continuously enrolled in 2011 (including due to death that year) or were hospitalized on January 1, 2011, were older, less likely to be female, and sicker than those who were included (eAppendix C).

TABLE 1. Characteristics of the Study Sample (N = 117,977), Their Ambulatory Visits During the Baseline Year, and Their Utilization of ED Visits and Hospital Admissions Over 2 Years of Follow-Up

Patient Characteristics	
Age, years, mean (SD)	77.2 (7.3)
Gender, female	60.8%
Number of chronic conditions[a]	
0	1.4%
1-2	18.6%
3-4	39.1%
≥5	41.0%
Charlson-Deyo score	
Mean (SD)	1.5 (1.6)
Median (range)	1 (0-16)
Ambulatory Visits	
Number of ambulatory visits per patient, median (range)[b]	12 (4-76)
Number of unique ambulatory providers per patient, median (range)	5 (1-22)
Proportion of visits with the most frequently seen ambulatory provider, median (range)	0.40 (0.08-1.00)
ED Visits	
Proportion of patients with ≥1 ED visit during the study period	0.25
Observation time until ED visit or censoring, median (range)	1.7 years (1 day-2.0 years)
Hospital Admissions	
Proportion of patients with ≥1 hospital admission during the study period	0.33
Observation time until hospital admission or censoring, median (range)	2.0 years (1 day-2.0 years)

ED indicates emergency department.

[a]Percentages may not add up to 100 due to rounding.

[b]Beneficiaries were included if they had 4 or more ambulatory visits in the baseline year (see eAppendix C for characteristics of those who were excluded).

Ambulatory Care at Baseline

Among those who were included, the typical (median) beneficiary had 12 ambulatory visits with 5 unique providers in the baseline year (Table 1). The typical beneficiary also had 40% of ambulatory visits with their most frequently seen provider. As the proportion of visits with the most frequently seen provider decreased, fragmentation increased (**Table 2**). Just 2.5% of the sample had 1 provider for all visits (resulting in a fragmentation score equal to 0.00).

Associations With ED Visits and Hospital Admissions

One-fourth of beneficiaries (25%) had 1 or more ED visits during follow-up. The median observation time until an ED visit or censoring (for the ED visit models) was 1.7 years. One-third of beneficiaries (33%) had 1 or more hospital admissions during follow-up. The median observation time until a hospital admission or censoring was 2.0 years. Schoenfeld residuals and zph tests showed that our models did not violate the underlying statistical assumptions.

Among those with 0 chronic conditions, having fragmented care did not increase the hazard of an ED visit (**Table 3**). Among those with 1 or more chronic conditions, having the most (vs the least) fragmented care significantly increased the hazard of an ED visit, by a magnitude of 13% for those with 1 to 2 chronic conditions ($P < .01$), 14% for those with 3 to 4 chronic conditions ($P < .0001$), and 10% for those with 5 or more chronic conditions ($P = .001$). Some but not all of the intermediate fragmentation categories were also associated with an increased hazard of an ED visit.

Among those with 0 chronic conditions, having fragmented care did not increase the hazard of a hospital admission (**Table 4**). Among those with 1 to 2 or 3 to 4 chronic conditions, having the most (vs the least) fragmented care significantly increased the hazard of a hospital admission, by a magnitude of 14% for those with 1 or 2 chronic conditions ($P < .01$) and 6% for those with 3 or 4 chronic conditions ($P < .05$). Among those with 5 or more chronic conditions, having the most fragmented care decreased the adjusted hazard of a hospital admission by 5% ($P = .03$). Most intermediate fragmentation categories were not associated with a significant difference in the hazard of admission.

TABLE 2. Patterns of Ambulatory Care in the Baseline Year, Stratified by Extent of Healthcare Fragmentation

	Fragmentation Category, Based on Reversed BBI Scores[a]	Reversed BBI Score Range[b]	n	Ambulatory Visits, Median (IQR)	Unique Ambulatory Providers, Median (IQR)	Proportion of Visits With Most Frequently Seen Provider, Median (IQR)
Most fragmented care	1	0.89-1.00	22,458	13 (8-20)	8 (6-10)	0.24 (0.20-0.28)
	2	0.83-0.89	25,540	14 (9-20)	7 (5-8)	0.32 (0.28-0.36)
	3	0.76-0.83	22,287	13 (9-19)	5 (4-7)	0.40 (0.36-0.43)
	4	0.62-0.76	24,706	11 (8-17)	4 (3-5)	0.50 (0.47-0.56)
Least fragmented care	5	0.00-0.62	22,986	8 (6-13)	2 (2-3)	0.73 (0.67-0.83)

BBI indicates Bice-Boxerman Index; IQR, interquartile range.

[a]Fragmentation categories reflect BBI scores that have been reversed (equal to 1 minus the raw BBI score) and then divided into quintiles.

[b]The boundaries shown are rounded; actual boundaries between quintiles were calculated to the fifth decimal place, so the categories are mutually exclusive. The boundaries shown were derived from the data used in the models for predicting hospitalization.

TABLE 3. Ambulatory Healthcare Fragmentation and Association With Subsequent ED Visits, Stratified by Number of Chronic Conditions[a]

	0 Chronic Conditions		1-2 Chronic Conditions		3-4 Chronic Conditions		≥5 Chronic Conditions	
	n = 1615		n = 21,963		n = 46,089		n = 48,310	
	HR	*P*	HR	*P*	HR	*P*	HR	*P*
Fragmentation category								
1 (most fragmentation)	1.03	.89	1.13	<.01	1.14	<.0001	1.10	.001
2	1.26	.14	1.12	.01	1.09	<.01	1.07	.02
3	0.83	.37	1.05	.31	1.07	.04	1.02	.52
4	1.14	.46	1.13	<.01	1.05	.12	0.98	.58
5 (least fragmentation)	Ref	–	Ref	–	Ref	–	Ref	–
Age	1.02	.01	1.03	<.0001	1.02	<.0001	1.02	<.0001
Female	0.89	.31	1.02	.50	1.14	<.0001	1.17	<.0001
Number of ambulatory visits	1.04	<.0001	1.02	<.0001	1.02	<.0001	1.02	<.0001
Charlson-Deyo score	0.97	.64	1.05	<.0001	1.02	.004	1.03	<.001

ED indicates emergency department; HR, hazard ratio; ref, reference.

[a]These results were derived using multivariate Cox models. Fragmentation categories reflect Bice-Boxerman Index scores that have been reversed (equal to 1 minus the raw score) and then divided into quintiles. The *P* value for the interaction term for fragmentation category*chronic condition category was .16.

TABLE 4. Ambulatory Healthcare Fragmentation and Association With Subsequent Hospital Admissions, Stratified by Number of Chronic Conditions[a]

	0 Chronic Conditions		1-2 Chronic Conditions		3-4 Chronic Conditions		≥5 Chronic Conditions	
	n = 1615		n = 21,963		n = 46,089		n = 48,310	
	HR	*P*	HR	*P*	HR	*P*	HR	*P*
Fragmentation category								
1 (most fragmentation)	0.92	.63	1.14	<.01	1.06	.04	0.95	.03
2	0.85	.38	1.07	.14	1.03	.22	0.96	.05
3	0.93	.74	1.05	.33	1.00	.86	0.93	<.01
4	0.90	.56	1.02	.62	0.96	.16	0.99	.58
5 (least fragmentation)	Ref	–	Ref	–	Ref	–	Ref	–
Age	1.06	<.0001	1.05	<.0001	1.05	<.001	1.03	<.0001
Female	1.06	.66	0.90	<.001	0.98	.28	1.07	<.0001
Number of ambulatory visits	1.05	<.0001	1.03	<.0001	1.03	<.0001	1.02	<.0001
Charlson-Deyo score	1.00	.96	1.18	<.0001	1.15	<.0001	1.13	<.0001

HR indicates hazard ratio; ref, reference.

[a]These results were derived using a multivariate Cox model. Fragmentation categories reflect Bice-Boxerman Index scores that have been reversed (equal to 1 minus the raw score) and then divided into quintiles. The *P* value for the interaction term for fragmentation category*chronic condition category was <.0001.

Sensitivity analyses using 2 alternative fragmentation indices (**eAppendices D** and **E**) showed results consistent with our base-case analyses, both for ED visits and hospital admissions.

DISCUSSION

In this study of Medicare FFS beneficiaries 65 years and older, having highly fragmented care (in the highest quintile of fragmentation scores) seemed to have the greatest impact on subsequent outcomes, suggesting a potential threshold effect. Those with highly fragmented care had a median of 13 ambulatory visits with 8 providers, and their most frequently seen provider typically accounted for just 24% of ambulatory visits. The relationship between highly fragmented care and subsequent outcomes varied by the number of chronic conditions.

Among those with 1 to 2 or 3 to 4 chronic conditions, having the most (vs the least) fragmented care significantly increased the hazard of an ED visit and, separately, increased the hazard of a hospital admission ($P < .05$ for each comparison). Among those with 5 or more chronic conditions, having the most (vs the least) fragmented care significantly increased the hazard of an ED visit but decreased the hazard of a hospital admission ($P < .05$ for each comparison). This observation could mean that having many providers for these complex patients is often necessary and sometimes protective. We did not find an association between fragmentation and ED visits or hospital admissions among those with 0 chronic conditions, perhaps because those who are relatively healthy are not as vulnerable to the adverse effects of fragmented care.

Our finding of an increased hazard of ED visits for those with fragmented care and at least 1 chronic condition is consistent with findings from 2 other studies, which were disease-specific: 1 that focused on patients with diabetes[7] and another that focused on patients with diabetes, congestive heart failure, or chronic obstructive pulmonary disease.[6] Our finding of an increased hazard of hospital admissions for those with fragmented care and 1 to 4 chronic conditions is also consistent with studies that expressed the increased hazard as a function of a 0.1-point increase on a continuous fragmentation scale.[6,8] Thus, our work expands the literature by including Medicare beneficiaries regardless of disease type and by quantifying the magnitude of the hazard for the most fragmented care.

The results have implications for the design of future interventions to improve healthcare, in terms of which patients to target for intervention. Many previous efforts to improve healthcare quality and efficiency have targeted the sickest patients,[24,25] which makes sense, because these patients account for a disproportionate amount of healthcare utilization.[26] However, the effectiveness of these programs has been mixed,[24,27] perhaps in part because it is

difficult to modify the need for care among the sickest patients. Our study findings suggest that there may be inefficient utilization of healthcare services among those with a moderate number of chronic conditions. Inefficient utilization may be modifiable, and decreasing inefficiency among the many people with a moderate disease burden may have a large aggregate impact.

The results of this study also have implications for what kinds of future interventions to test. Previous efforts to improve care coordination, such as the patient-centered medical home model of care, have not specifically measured or targeted patterns of ambulatory care within individual patients.[28] The few previous studies that tried to explicitly decrease fragmentation were small trials but had promising results. A randomized controlled trial of 776 men 55 years and older at a Veterans Administration hospital in Vermont found that those who were randomized to "continuity" (routinely scheduled appointments with the same provider) had fewer emergent hospital admissions and shorter average length of stay than those randomized to "discontinuity" (a die tossed at each scheduled follow-up visit, with a 33% chance of being sent to a different provider).[29] A randomized controlled trial of 409 pediatric patients in Seattle, Washington, was successful in decreasing fragmentation through the use of custom alerts built into electronic health records, notifying providers in real time if they were seeing patients with highly fragmented care.[30]

Limitations

This study has several limitations. First, it is observational, and we cannot rule out unmeasured confounding. Second, we cannot draw conclusions about the medical appropriateness of the care patterns observed. It is possible that fragmentation increases appropriately when patients become acutely ill and that this appropriate use of multiple providers occurs just prior to an ED visit or hospital admission. Future studies with more granular clinical data are needed to help clarify issues of appropriateness. Third, we did not measure communication across physicians. Although having fragmented care may increase the risk of gaps in communication across providers, its presence should not be interpreted as a definite lack of care coordination. Fourth, we did not have data on practice characteristics or practice affiliation, so we were not able to account for those. Fifth, this study took place in 1 region, which may limit generalizability; however, this region is a multipayer, multiprovider healthcare market, which may make it similar to other communities. Future studies could include market characteristics (such as rural vs urban and number of providers per population) as additional explanatory variables. Sixth, this study included only FFS Medicare beneficiaries; results may not apply to patients with other insurance types.

Even with these limitations, this study is relevant, because the importance of healthcare fragmentation has grown with national changes in provider reimbursement. Medicare is moving away from FFS reimbursement toward alternative payment models.[31,32] These models require providers to be clinically and financially responsible for all of a patient's care, not just the care that they themselves provide. Thus, an excess burden of ED visits and hospitalizations from fragmented ambulatory care would be highly relevant to providers seeking to succeed under these new payment models. Large studies to explicitly test and compare the effectiveness of strategies for decreasing fragmentation are warranted. Additional studies could also consider the effect of fragmentation on rates of readmission, given that that is a time when patients are especially vulnerable to the effects of suboptimal care delivery.[33-35]

CONCLUSIONS

Highly fragmented care can independently increase the hazard of an ED visit or hospital admission, even among those with a moderate number of chronic conditions. Reducing fragmentation for those with a moderate number of chronic conditions may both improve quality and reduce costs. ■

Acknowledgments

This study was funded by the Commonwealth Fund (grant #20140960). The authors thank Leah Hellerstein, BA, and Yesenia Miranda, BA, for their assistance with reviewing the literature. The authors thank the New York State Department of Health for facilitating access to the data. The conclusions do not necessarily reflect the views of the Commonwealth Fund or New York State Department of Health.

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Source of Funding: This work was supported by the Commonwealth Fund (grant #20140960).

Author Disclosures: The authors report no relationship or financial interest with any entity that would pose a conflict of interest with the subject matter of this article.

Authorship Information: Concept and design (LMK, SSS); acquisition of data (LMK, RJ, SSS); analysis and interpretation of data (LMK, JKS, MR, RJ); drafting of the manuscript (LMK); critical revision of the manuscript for important intellectual content (LMK, JKS, MR, SSS); statistical analysis (JKS, MR, RJ); obtaining funding (LMK); administrative, technical, or logistic support (LMK); and supervision (LMK).

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eAppendix A. Formulae for 3 Fragmentation Indices[15,16]

A. The Bice-Boxerman Index (BBI)

$$BBI = \frac{\left(\sum_{i=1}^{p} n_i^2\right) - n}{n\,(n-1)}$$

Where n = total number of visits in a 12-month period
n_i = number of visits to provider i
p = total number of providers

B. The Herfindahl-Hirschman Index (HHI)

$$HHI = \sum_{i=1}^{p} \left(\frac{n_i}{n}\right)^2$$

Where n = total number of visits in a 12-month period
n_i = number of visits to provider i
p = total number of providers

C. The Usual Provider Continuity (UPC) Index

$$UPC = max\left(\frac{n_i}{n}\right)$$

Where n = total number of visits in a 12-month period
n_i = number of visits to provider i

Note that for all of these indices, we reversed the direction of the index (1 – raw score) and divided scores into quintiles, as described in detail in the Methods section.

eAppendix B. Chronic Conditions Listed in the Centers for Medicare and Medicaid Services Chronic Conditions Warehouse[17]

1. Acquired hypothyroidism
2. Acute myocardial infarction
3. Alzheimer's disease*
4. Alzheimer's disease and related disorders or senile dementia*
5. Anemia
6. Asthma
7. Atrial fibrillation
8. Benign prostatic hyperplasia
9. Cataract
10. Chronic kidney disease
11. Chronic obstructive pulmonary disease and bronchiectasis
12. Depression
13. Diabetes
14. Glaucoma
15. Heart failure
16. Hip/pelvic fracture
17. Hyperlipidemia
18. Hypertension
19. Ischemic heart disease
20. Osteoporosis
21. Rheumatoid arthritis / osteoarthritis
22. Stroke / transient ischemic attack
23. Female / male breast cancer
24. Colorectal cancer
25. Prostate cancer
26. Lung cancer
27. Endometrial cancer

*These two categories were combined to avoid double-counting.

eAppendix C. Comparing the Study Sample to the Patients Who Were Excluded*

Patient Characteristics	Total	Included	Excluded Group 1: ≤3 Ambulatory Visits	Excluded Group 2: Not Continuously Enrolled in 2011 or Hospitalized on 1/1/2011	*P*: Included vs Excluded Group 1	*P*: Included vs Excluded Group 2
N	139,394	117,977	13,439	7978		
Age, years, mean (SD)	76.8 (7.5)	77.2 (7.3)	75.9 (8.1)	80.0 (8.4)	<.0001	<.0001
Gender, female, %	60.4%	60.8%	60.3%	55.9%	.30	<.0001
Number of CCs					<.0001	<.0001
0, %	2.3%	1.4%	11.8%	0.9%		
1-2, %	21.5%	18.6%	52.6%	10.9%		
3-4, %	37.5%	39.1%	29.5%	27.8%		
≥5, %	38.7%	41.0%	6.2%	60.4%		
Charlson-Deyo Index, mean (SD)	1.5 (1.7)	1.5 (1.6)	0.5 (0.9)	2.8 (2.5)	<.0001	<.0001

CC indicates chronic condition.

*P values are based on Wilcoxon rank-sum tests for continuous variables and chi-squared tests for categorical variables.

eAppendix D. Sensitivity Analyses Measuring Fragmentation With a Reversed Herfindahl-Hirschman Index*

	0 Chronic Conditions		1-2 Chronic Conditions		3-4 Chronic Conditions		≥5 Chronic Conditions	
	n = 1615		n = 21,963		n = 46,089		n = 48,310	
	HR	***P***	**HR**	***P***	**HR**	***P***	**HR**	***P***
Fragmentation and Emergency Department Visits								
Fragmentation category								
1 (most fragmentation)	1.16	.46	1.21	<.001	1.16	<.0001	1.09	.005
2	1.15	.40	1.12	.01	1.11	.001	1.06	.04
3	1.11	.55	1.09	.05	1.10	.002	1.02	.51
4	1.13	.44	1.11	.01	1.00	.95	0.94	.07
5 (least fragmentation)	Ref	--	Ref	--	Ref	--	Ref	--
Age	1.02	.01	1.03	<.0001	1.02	<.0001	1.02	<.0001
Gender, female	0.89	.31	1.02	.58	1.13	<.0001	1.17	<.0001
Number of ambulatory visits	1.03	<.001	1.02	<.0001	1.02	<.0001	1.02	<.0001
Charlson-Deyo Index	0.97	.68	1.05	<.001	1.02	.005	1.03	<.0001
Fragmentation and Hospital Admissions								
Fragmentation category								
1 (most fragmentation)	1.10	.64	1.31	<.0001	1.10	.001	0.95	.03
2	0.94	.74	1.14	.005	1.05	.11	0.92	<.001
3	0.72	.08	1.08	.09	0.99	.71	0.95	.03
4	0.84	.31	1.03	.53	0.95	.07	0.95	.05
5 (least fragmentation)	Ref	--	Ref	--	Ref	--	Ref	--
Age	1.06	<.0001	1.06	<.0001	1.05	<.0001	1.03	<.0001
Gender, female	1.04	.75	0.90	<.001	0.98	.25	1.07	<.0001
Number of ambulatory visits	1.04	<.0001	1.03	<.0001	1.03	<.0001	1.02	<.0001
Charlson-Deyo Index	1.01	.95	1.17	<.0001	1.15	<.0001	1.13	<.0001

* These results were derived using a multivariate Cox models. Fragmentation categories reflect Herfindahl-Hirschman scores that have been reversed (equal to 1 minus the raw score) and then divided into quintiles. The *P* value for the interaction term for fragmentation category*chronic condition category was .20 in the emergency department visit model and <.0001 in the hospital admissions model.

eAppendix E. Sensitivity Analyses Measuring Fragmentation With a Reversed Usual Provider Continuity Index

	0 Chronic Conditions		1-2 Chronic Conditions		3-4 Chronic Conditions		≥5 Chronic Conditions	
	n = 1615		n = 21,963		n = 46,089		n = 48,310	
	HR	***P***	**HR**	***P***	**HR**	***P***	**HR**	***P***
Fragmentation and Emergency Department Visits								
Fragmentation category								
1 (Most fragmentation)	0.96	.82	1.13	.01	1.12	<.001	1.07	.01
2	1.25	.19	1.09	.07	1.06	.08	1.07	.02
3	0.91	.59	1.10	.04	1.09	<.01	1.00	.92
4	1.08	.61	1.06	.16	1.01	.69	0.98	.58
5 (Least fragmentation)	Ref	--	Ref	--	Ref	--	Ref	--
Age	1.02	.01	1.03	<.0001	1.02	<.0001	1.02	<.0001
Gender, female	0.90	.33	1.02	.49	1.14	<.0001	1.17	<.0001
Number of ambulatory visits	1.03	<.001	1.02	<.0001	1.02	<.0001	1.02	<.0001
Charlson-Deyo Index	0.97	.69	1.05	<.001	1.02	.004	1.03	<.0001
Fragmentation and Hospital Admissions								
Fragmentation category								
1 (Most fragmentation)	1.10	.61	1.19	<.001	1.07	.02	0.94	<.01
2	0.74	.15	1.09	.05	1.00	.96	0.94	<.01
3	1.05	.79	1.03	.46	1.02	.48	0.97	.14
4	0.78	.17	1.00	.97	0.99	.20	0.99	.73
5 (Least fragmentation)	Ref	--	Ref	--	Ref	--	Ref	--
Age	1.06	<.0001	1.05	<.0001	1.05	<.0001	1.03	<.0001
Gender, female	1.05	.71	0.90	<.001	0.98	.29	1.07	<.0001
Number of ambulatory visits	1.05	<.0001	1.03	<.0001	1.03	<.0001	1.02	<.0001
Charlson-Deyo Index	1.00	.96	1.18	<.0001	1.15	<.0001	1.13	<.0001

* These results were derived using a multivariate Cox models. Fragmentation categories reflect Usual Provider Continuity scores that have been reversed (equal to 1 minus the raw score) and then divided into quintiles. The *P* value for the interaction term for fragmentation category*chronic condition category was .23 in the emergency department visit model and <.0001 in the hospital admissions model.