The Impact of Alternative Payment Models on Care Coordination

by

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Dedication

To the people of color, women, and mothers at the University of Michigan who risked so much in the pursuit of answering questions that matter. And to Avery Cooper, I hope you never stop asking questions.

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Abstract

Each year, poorly coordinated care in the US healthcare system results in $25-45 billion in unnecessary spending due to avoidable complications and readmissions. Coordinating care between healthcare organizations is particularly challenging since there are many opportunities for communication breakdowns when information travels across organizational boundaries. Recent healthcare reform programs have developed several innovative models of paying providers, collectively known as Alternative Payment Models (APMs), which create incentives for providers to reduce costs. Policy discussions surrounding APMs are usually focused on their potential impact on care coordination and its implications for cost reduction. However, these models reward providers for reducing costs through *any means*, not only care coordination. Prior studies have found mixed evidence on the impact of APMs on cost and quality; but little is known about the impact of APMs on care coordination directly.

Using national datasets on acute-care hospitals in the US, my dissertation investigates the impact of hospital participation in APMs on 3 measures of care coordination: patient engagement during hospital care transitions, health information exchange, and hospital-SNF referral patterns.

In Chapter 1, I ask whether patient engagement during hospital care transitions is associated with reduced readmission rates, and whether APM-participation is associated with improved patient engagement. I use panel analysis techniques on retrospective observational data on 2,685 hospitals from 2013-2017. I found that patient engagement was associated with reduced readmission rates, but APM-participating hospitals were not improving patient engagement

compared to non-APM hospitals. These findings suggest that APM-participating hospitals may be overlooking patient engagement as an important patient-centered strategy for reducing healthcare costs.

In Chapter 2, using cross-sectional analysis on retrospective observational data on 798-1730 hospitals from 2014-2015, I evaluate the association between APM participation and four measures of health information exchange (HIE). Together, these measures paint a detailed picture of how well hospitals are sending information for patients that are discharged from a hospital setting. I found that APM-participating hospitals sent data for fewer patients, but routinely sent more data types, to more partner types, using a greater variety of exchange approaches. Findings from this chapter suggest that APM-participating hospitals may be investing in HIE infrastructure with a selective group of partners, rather than engaging in more community-based approaches to HIE.

Finally, in Chapter 3, I assess the impact of Medicare's Bundled Payment for Care Improvement (BPCI) program on hospital-SNF referral patterns. Social network theory posits that hospitals with fewer SNF partners, or more concentrated SNF referral patterns may have an easier time coordinating care for their patients. I conduct a panel analysis on 2,354 hospitals from 2009-2015 to assess whether BPCI participation leads to reductions in SNF referrals, a pruning of SNF partners, or more concentrated SNF referrals; and whether the quality of SNF partners improves after hospitals join the BPCI program. I found that participation in the BPCI program did not lead to significant changes in hospital-SNF referral patterns, and the quality of SNF partners improved after hospitals joined the BPCI program. These findings suggest that BPCI participating hospitals are not changing referral patterns to favor higher-quality SNFs; instead, the quality of SNFs in BPCI-participating hospital referral networks may be improving.

As a whole, this dissertation contributes to understanding whether APMs improve care coordination and suggests that policymakers may need to consider more explicit methods of incentivizing care coordination.

Introduction

The US healthcare system is based on a fee-for-service (FFS) payment model where providers are paid on the basis of the type and quantity of services provided. Under FFS, providers are not compensated for coordinating care for their patients. As a result, the US healthcare system is one of the most fragmented healthcare systems in the world. Fragmented care costs the US an estimated $25-45 billion annually in unnecessary medical spending (1). Fragmented care for elderly patients during hospital care transitions is especially problematic as discharged patients are particularly vulnerable during hospital care transitions. Care coordination, or the deliberate organizing of care activities and sharing information among all participants concerned with patient care, is a strategy to improve care fragmentation. An estimated 25-35% of hospital readmissions are potential avoidable with improved care coordination (2, 3), however, as long the FFS payment model remains the predominant model of provider compensation in the US, providers have little incentive to systematically improve care coordination for their patients.

With healthcare costs rising by 3.0-5.8% annually since 2011 (4), the Center for Medicare and Medicaid Services (CMS) have been experimenting with policies to reduce healthcare spending. Over the past ten years, three programs, collectively known as "Alternative Payment Models (APMs)," have emerged as promising solutions to reduce costs for Medicare patients: Accountable Care Organizations (ACOs), bundled payments, and Medical Homes. According to neo-classical microeconomic theory, payment mechanisms used by APMs should motivate providers to lower healthcare spending growth in order to earn financial incentives. Specifically, ACOs do this by holding organizations accountable for the cost of care delivered to a shared

patient population each year; if spending on ACO patients comes under a target benchmark, ACO providers receive a portion of the shared savings. The Medicare Bundled Payments for Care Improvement (BPCI) program pays participating hospitals a target price per covered episode for all services delivered both during and *after* the hospitalization. And organizations that are certified as medical homes are paid using payment mechanisms similar to ACOs and bundled payments, in addition to receiving per-member per-month allowances to facilitate care management.

Policy makers believe that APMs will reduce cost growth through improved care coordination; in fact, on their website, CMS almost exclusively describes APMs in terms of their expected impact on care coordination (5-7). This belief is supported by resource dependency theory. According to resource dependency theory, organizations depend on resources in their environment to survive, and may attempt to exert control over their external environment in order to ensure access to those resources (8, 9). Thus, hospitals participating in APMs may engage in greater care coordination with external partners to reduce the risk that their patients experience a costly readmission, in service of maximizing financial gains.

Yet, despite the hype surrounding the role of care coordination in APMs, APMs reward providers for reducing costs through *any* mechanism, not specifically care coordination (10). These policies, coupled with findings from recent studies that find that care coordination interventions may actually *increase* healthcare spending (11), suggests that policymakers should not blindly assume that APMs are leading to improvements in care coordination. By assuming that care coordination is a mechanism to promote cost containment, policy makers have written APM policies that do little to explicitly incentivize hospitals to improve care coordination over other strategies for reducing costs (11). For example, ACOs incentivize cost containment along

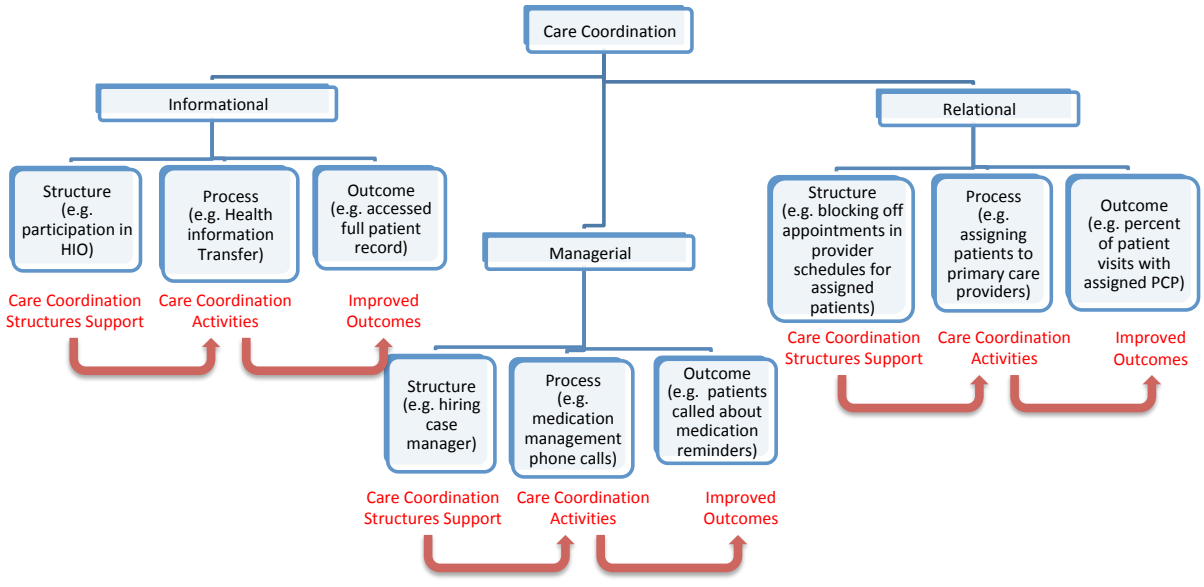
the entire care continuum. Given that hospital services make up the lion's share of healthcare spending in the US, this suggests that ACOs are likely to reduce hospital utilization in the first place, perhaps reducing the need to invest in care coordination strategies at all. Along the same lines, hospitals in the BPCI program receive a target price for all services (acute and post-acute care), incentivizing hospitals to reduce post-acute care utilization; which may again reduce the incentive for hospitals to invest in care coordination. Finally, while medical home accreditation programs exist for both ambulatory care practices and hospitals, Medicare does not offer a mechanism for hospitals to participate in their medical home programs, leading hospitals with medical homes very little incentive to improve care coordination for their patients.

Care coordination has historically been a difficult construct to measure in health services research because it encompasses different dimensions, domains, and perspectives (42); each measurable component of care coordination is just a small part of a larger system of how care is coordinated for patients. To illustrate how complex care coordination measurement is, I describe a model of care coordination that I developed from the existing literature (Figure 1), and how the measures that I use in my chapters can be understood as just one part of a greater picture.

The first tier of the model draws on the Continuity of Care framework developed by Haggerty et al, which describes care coordination along three dimensions: informational, managerial, and relational. Information continuity refers to the use of historical information to provide appropriate care. Managerial continuity refers to a consistent and coherent approach to the management of health. And relational continuity refers to an ongoing relationship between patients and his/her providers (43,44). Within each dimension, a specific measure of care coordination can then be categorized along three domains (structure, process, and outcome), which draws from the well-known Donabedian approach to understanding care quality (21).

According to Donabedian, infrastructure impacts healthcare processes, which in turn affects outcomes. For example, along the information dimension of care coordination, a hospital may invest in information sharing technology to facilitate information flows to a post acute care provider (structure), and establish workflows for routinely transmitting summary of care records for discharged patients (process). The combined improvements in structure and process then impact the percent of patients for whom the complete hospitalization record is accessed to inform appropriate follow up care (outcome). Finally, each construct can also be viewed from different perspectives: patient/caretaker, provider, or system. The example above measures information coordination from the perspective of the system. These constructs could also be measured from the patient or provider perspective. E.g. a patient could assess how well information was communicated to him/her at discharge (see Chapter 1).

Figure 1. Care Coordination Model



Across the three chapters of my dissertation, I measure care coordination using nine different measures. I chose these measures because they reflect multiple dimensions, domains, and perspectives on care coordination that can be measured repeatedly over time at the national level. Together, these measures provide a multi-faceted view of care coordination and its role in APMs, yet they still fall short of measuring care coordination along each possible combination of dimension, domain, and perspective. While findings from my dissertation show mixed results on the impact of APMs on care coordination across all three dimensions, is it by no means an exhaustive body of work and much still needs to be done to understand how APMs impact care coordination for hospital care transitions in all dimensions, domains, and perspectives. At the moment, this work is limited by the availability of high-quality longitudinal data.

To date, very little is known about the impact of APMs on care coordination during the hospital care transition. It may be that APMs lead to little or no improvements in care coordination, despite the growing public belief that care coordination plays an important role in APMs. The dissonance between what is expected and what has been studied reveals a large gap in knowledge that is critical for creating policies that effectively improve care coordination. To date, there have been no robust quantitative analysis on the impact of APMs on care coordination during hospital care transitions; instead, the bulk of the research on APMs has focused on APM formation and its effects on service utilization. A small body of emerging research suggests that APMs are achieving only modest cost savings, however, very little is known about whether care coordination is a mechanism through which APMs are achieving these cost savings. The goal of this dissertation is to inform the current policy debate on the impact of APMs on healthcare spending by assessing whether and how APMs are improving care coordination during hospital care transitions. Findings will help us to understand if APMs are achieving cost savings through

care coordination, or if other mechanisms, such as reduce utilization or changes in billing practices, are responsible for this modest improvement in cost savings.

In Chapter 1, I examine whether patient engagement during hospital care transitions is associated with lower readmission rates and whether APM-participating hospitals improve the level of patient engagement during hospital care transitions. Prior studies have found that engaged patients report a better ability to coordinate their own care and communicate with their providers, which may lead to reductions in readmission rates. Given that both care coordination and readmission rates are important goals for hospitals participating in APMs, it is reasonable to expect that APM-participating hospitals would improve patient engagement as a strategy to meet both these goals. This analysis was conducted using panel analysis techniques on longitudinal data from 2,685 hospitals from 2013-2017. The dataset was compiled using novel linkages between a variety of national datasets including CMS's Hospital Compare, the Area Health Resource File, CMS's publicly available datasets on BPCI participation, the American Hospital Association's annual survey, and the Leavitt Partner's ACO database.

I found that patient engagement is associated with improved readmission rates, but I also found that hospitals that join APMs do not improve their levels of patient engagement. In fact, I found that BPCI participation is associated with declining levels of patient engagement, suggesting that patient engagement may be suffering at the expense of alternative strategies for reducing costs. Findings from my first dissertation chapter suggests that APM-participating hospitals may be neglecting the patient *experience* of care, and that APM-participating hospitals may be overlooking an important and effective patient-centered strategy to improving readmission rates.

In Chapter 2, I examine the association between APM participation and electronic health information exchange (HIE). HIE is critical component of care coordination. An estimated 12-34% of primary care doctors report missing discharge summaries at the first follow up visit after a patient hospitalization, and even if a discharge summary is received in time, many contain inaccurate or missing information (12). HIE has been shown to improve the timeliness, accuracy, and completeness of information transfers during hospital care transitions by standardizing information sent to receiving providers during hospital discharges, permitting exchange of discreet data types, allowing providers to look up specific information at the point of care, and facilitating free-flow of medical information between medical record systems with minimal human interpretation (13, 14). Most prior studies of HIE have used binary measures of information exchange, measures that fail to capture whether HIE is used to improve care coordination systematically. These measures do little to tell us about whether HIE is contributing to the goal of "getting the right information to the right person at the right time." In this chapter of my dissertation, I employ four novel and more detailed measures of HIE: volume of patients for whom information is exchanged, diversity of data types, breadth of partner types, and depth of exchange approach. Volume of patients refers to the percent of patients for whom data is exchanged following a hospital discharge. Diversity of data types refers to the kinds of data that are routinely sent from a hospital to a receiving provider. Breadth of partner types refers to the kinds of partner types that a hospital routinely sends data to. And depth of exchange approach refers to the method through which data is routinely exchanged. This analysis was conducted using 2014-2015 data on 798 hospitals for the volume analysis and 1730 hospitals for the diversity, breadth, and depth analyses. The dataset was compiled using novel linkages between a variety of datasets of HIE use, including CMS's publicly available datasets on the EHR incentive

program and BPCI participation, the American Hospital Association's annual survey and IT supplement, the Area Health Resource File, and the Leavitt Partner's ACO database. I found that hospitals in APMs have greater engagement in the diversity, breadth, and depth dimensions of HIE, and poorer engagement in the volume dimension. This finding suggests that HIE infrastructure may be improving under APMs, but HIE *use* may be limited to a select group of affiliated partners.

Finally, in Chapter 3, I examine how relationships between hospitals and skilled nursing facilities change for hospitals that join the BPCI program. Specifically, I draw on social network theory, a method used for quantifying relationships between entities, to assess how patient sharing patterns change for hospitals that join the BPCI program for joint replacement. Social network theory posits that providers whose networks are concentrated around focal points have an easier time coordinating and monitoring services across many agencies (15, 16) and controlling and replicating behavior of other providers in the network (17). This suggests that hospitals that discharge patients to fewer post-acute care partners, or have more concentrated post-acute care networks, may have an easier time coordinating care for their patients because they can invest in partner-specific activities and infrastructure that improve care coordination for more of their patients. Indeed, prior qualitative studies have found that under the BPCI program, many hospitals establish networks of "preferred skilled nursing facilities (SNFs)" as a strategy for improving care coordination (18, 19).

The BPCI program for joint replacement has been shown to be successful in reducing costs while preserving quality of care for patients (19, 20). Yet little research has been done on the mechanism behind this success. In this context, I hypothesized that preferred SNF networks may be one way that BPCI-participating hospitals are improving care for their patients. For this

chapter of my dissertation, I ask whether the BPCI program is leading to changes in hospital-SNF referral networks that reflect relationships that are easier to coordinate care (i.e. more concentrated networks with fewer SNF partners). I then ask what kinds of SNFs receive a larger portion of patient referrals both before and after a hospital joins the BPCI program in order to understand whether BPCI participation leads to higher quality SNF networks.

This analysis was conducted on a six-year panel of data on 139,452 discharges from 2,354 hospitals to 10,383 SNFs. First, I used national Medicare claims data to identify patients who underwent joint replacement in US hospitals and are newly admitted to skilled nursing facilities upon discharge. I then used this data to construct a panel dataset of hospital-SNF referral networks from 2009-2015, and calculate the number of discharges, concentration of SNF referrals, and number of SNF patients per hospital per year. Finally, by linking this network data to data on hospital characteristics from the American Hospital Association's annual survey, and SNF characteristics from CMS's Nursing Home Compare dataset, I am able to assess whether the quality of a hospital's SNF partners improve after a hospital joins the BPCI program.

I found that, consistent with other studies, SNF utilization decreased after a hospital joins the BPCI program (19, 20). I also found that the number of SNF partners and concentration of SNF referrals did not change, and that after joining the BPCI program, the quality of SNF partners increased significantly. Taken together, these findings suggest that hospitals in the BPCI program are not dropping lower quality SNFs from their networks in exchange for higher quality SNFs, as I first hypothesized. Instead, these findings suggest that the quality of SNFs in pre-existing BPCI-participating hospital networks may be improving in order to maintain referrals from BPCI-participating hospitals.

Taken as a whole, this dissertation is an important step towards understanding whether APMs have succeeded in their goal of improving care coordination. My results suggest that hospitals in APMs are engaging in some activities to exert control over their external environments in order to secure access to financial resources. Specifically, by increasing the variety of shared data types, ways of accessing data, and variety of partner types with whom they share information, hospitals in APMs may be improving information flows in order to reduce the risk of patients receiving lower quality post acute care from their referral partners. Similarly, by reducing the number of discharges to SNFs, hospitals in the BPCI program may be attempting to reduce the risk that they bear for post-acute care quality. However, my results also suggest that hospitals are not going "all in" on care coordination strategies, and are likely to be using other approaches to reduce costs. Specifically, I did not find that APM participation is associated with improvements in patient engagement during hospital care transitions (Chapter 1), the percent of discharged patients for whom information is exchanged electronically (Chapter 2), or hospital-SNF referral networks (Chapter 3).

Despite scoping constraints, this body of work has important implications for future policy. First, the biggest takeaway from this work is that payment models that incentivize reduced cost growth, *without specifying the exact mechanism* for reducing cost growth, may not be sufficient to improve hospital-based care coordination. This matters because care fragmentation is cited as one of the primary concerns of patients and policymakers, and has become a priority of health reform policies; yet, little is being done in current legislation to tie financial incentives to actual measures of care coordination. The assumption that care coordination necessarily leads to cost containment has erroneously led policymakers to focus exclusively on measures of cost containment as markers of successful health reform policies—to the detriment of implementing

policies that may explicitly target care coordination (10). If policymakers are serious about improving care coordination, more targeted mechanisms should be set in place, such as incorporating care coordination measures into evaluations of APM performance or reimbursing providers directly for care coordination activities. On the other hand, one could argue that certain outcomes, such as cost and patient outcomes, are the only metrics that should matter in health reform; and the exact mechanism whereby these outcomes are achieved should be left up to providers in order to spur innovation and experimentation. While this argument has been used in the past to justify the flexibility afforded to providers under the first Medicare APM's (the Medicare Shared Shavings ACO Program and the Bundled Payment for Care Improvement programs), my research shows that care coordination does not necessarily improve when providers are evaluated using these metrics alone. At this point in health reform, when enrollment in APMs is projected to increase significantly over the next few years, I believe that it is imperative to incorporate explicit measures of care coordination into APM policies in order to avoid unintended consequences that may adversely impact patient care.

Second, my dissertation reveals several unintended consequences of APM participation that policymakers should be aware of. In my first chapter, I found that BPCI participation is associated with a decrease in levels of patient engagement, suggesting that BPCI-participating hospitals may be improving costs at the expense of patient engagement. This is an important finding that feeds into the growing worry that, amidst the growing burden of documentation and quality improvement initiatives, providers are forgetting to engage patients meaningfully in their own care (22). Currently, the BPCI program and its successor, BPCI Advanced, do not incorporate any measures of patient engagement into program assessments. Doing so may help re-center the patient as the primary stakeholder in healthcare reform. It may be especially

important to consider the implications of this finding for underserved patients. For example, non-English speaking patients may be harder to engage during hospital care transitions. If BPCI-participating hospitals have poorer patient-engagement, it may be these patients who are disproportionately experiencing poorer quality patient engagement as a result. In my second chapter, I found that APM-participating hospitals engage in lower HIE volume than non-APM participating hospitals, suggesting that hospitals may restrict HIE efforts to a limited number of affiliated partners. This finding that suggests that, even under alternative, non-Fee for Service payment models, significant challenges still exist to improving broad HIE use. It will be important moving forward to take a long look at whether APMs are incentivizing the right relationships.

While this work represents an important contribution to our understanding of the effects of APMs on care coordination, it is not without its limitations. One major limitation is that this works focuses primarily on hospital-level care coordination and its association with hospital-participation in APMs. With the exception of the BPCI program, APMs have primarily targeted ambulatory-care level interventions; this is especially true for medical homes, in which the role of hospitals has not yet been fully developed. This limitation is most acutely illustrated in chapter 1, which evaluated patient engagement during hospital care transitions *at the point of discharge,* even though patient engagement *after* discharge is a more commonly cited strategy for improving care coordination under APMs. While results from this work suggest that APMs are not necessarily improving care coordination in hospitals, it is unable to speak to the impact of APMs in care coordination in ambulatory care practices. Care coordination in ambulatory care practices may be more important than hospital-based care coordination, as primary care providers are taking an increasingly larger role in coordinating care for their patients, especially

for those with complex care needs. However, due to the dearth of high quality national data on ambulatory care based care coordination structures, processes, and outcomes, this work remains a direction for future research at the time of this writing.

In addition, while all efforts were made to include a nationally representative sample of hospitals in each analysis, due to limitations in data collection, chapter 2 contains a smaller subset of hospitals that are larger and more technologically advanced than hospitals in the US as a whole. Therefore, the conclusion drawn about the association between APMs and HIE may be limited to more advanced hospitals. Relatedly, data on each HIE dimension were collected independently, and therefore we were unable to determine specifically what kinds of data were sent for what types of patients, to whom, and how. These are important questions that would allow us to gain a better picture of the utility of HIE and how it is used for different types of patients. It may be that APM-participating hospitals selectively engage in HIE for more complicated patients who require more care coordination, while leaving out patients with less care coordination needs.

Another important limitation is that data for all three analyses is limited to the first few years of APM participation. It may take time for payment models to cause meaningful changes in care coordination structures, processes, and outcomes. It will be important moving forward to continue to collect data on care coordination to fully understand how care coordination evolves with new models of healthcare delivery. Furthermore, as is the case for all retrospective data analyses, making causal inferences from retrospective data is challenging. As such, these papers describe statistical associations, rather than casual relationships. For example, in chapter 2, it is possible that APM participation does not *lead* to lower HIE volume, and higher HIE diversity, breadth, and depth. Instead, it may be that hospitals with lower HIE volume, and higher HIE diversity, breadth, and depth are selecting into APM programs.

Finally, the third chapter of my dissertation uses hospital-SNF referral patterns as an indicator of network structures that better support care coordination. There are other measures that could be used to understand care coordination in hospital-SNF relationships that would complement this study. For example, it would be valuable to understand how information sharing networks or hospital-SNF ownership structures change under bundled payments. These are important areas of research that underscores the need for better data on the state of care coordination in healthcare organizations in the US.

In summary, the US healthcare system is one of the most fragmented in the world, in large part because the majority of our healthcare is paid on a fee-for-service basis. Many policymakers hope that APMs will reduce care fragmentation by using alternatives to fee-for-service payments to incentivize providers to lower costs. Yet, as they are currently designed, APMs do not dictate that cost reductions need to be achieved through improved care coordination. Findings from this dissertation suggest that, without tying financial incentives directly to care coordination outcomes or processes, policymakers should not expect that APMs will necessarily lead to improvements in care coordination. Policies that aim to improve care coordination could either reimbursement providers directly for care coordination activities, or incorporate measures of care coordination quality into program evaluations.

Chapter 1. Improving Patient Engagement During Hospital Care Transitions: An Overlooked Strategy for Achieving Success Under Alternative Payment Models

Abstract

Hospital readmissions are a huge burden on the US healthcare system, costing Medicare an estimated $24 billion a year. One often-overlooked strategy for reducing readmission rates is improving patient engagement during hospital care transitions. Engaged patients report better care coordination and communication, which may lead lower risk of readmission. However, hospitals may be reluctant to support patient engagement interventions because of the burden it places on providers, who have competing priorities and high rates of burnout. Under current health reform policies, Alternative Payment Models (APMs) aim to reduce readmission rates and improve patient-centered care. Hospitals participating in APMs may dedicate resources to improve patient engagement as a way to meet both of these goals. Using national data on 2,685 hospitals from 2013-2017, we assess whether improvements in patient engagement leads to improved readmission rates, and whether hospitals that participate in APMs improve patient engagement. We found that patient engagement is associated with lower readmission rates, and that APM-participating hospitals are not improving patient engagement. These results suggest that hospitals may be overlooking an important and effective patient-centered strategy to improving readmission rates and patient centered care, and that APMs may be failing in their goal to improve patient-centered care.

Introduction

Fragmented care with insufficient coordination leads to medication errors and communication failures during hospital care transitions, resulting in unplanned hospital readmissions. One potentially effective, yet often neglected strategy for improving readmission rates is to improve care coordination through patient engagement (23-25). Patients who are engaged during hospital care transitions report a greater ability to obtain and communicate medical information to their providers, leading to better care coordination processes (26-30) and lower risk of hospital readmissions (31). Yet hospitals may be unwilling or unable to support patient engagement interventions during hospital care transitions because of the burden it places on physicians, who experience high rates of burnout due in large part to time constraints which may limit their ability to engage in patient engagement (32).

Hospitals participating in Alternative Payment Models (APMs) may be willing to dedicate resources to improve patient engagement during hospital care transitions for two reasons. APMs create direct financial incentives for hospitals to lower costs and reduce hospital readmission rates, and much of the policy-making rhetoric surrounding APMs tout the goal of improving patient-centered care (25). Specifically, Accountable Care Organizations (ACOs) reward providers for spending under a targeted amount for their patients, as long as certain quality metrics are met, including patient experience measures such as communication, shared decision making, and patient education. Improving patient engagement at the point of discharge may help hospitals in ACOs to lower costs (by reducing costly readmissions) and meet their patient experience benchmarks. Hospitals involved in medical homes may invest in patient engagement to uphold the required "Coordinated Care" standard necessary to maintain medical home accreditation. While, to date, Medicare medical home programs have primarily focused on

primary care practices, some hospitals may play an important role in facilitating care coordination for affiliated ambulatory care practices that are involved in medical homes programs. Finally, hospitals in the Bundled Payment for Care Improvement (BPCI) program are paid a targeted price per episode. Hospitals in the BPCI program may invest in patient engagement to reduce readmission rates and protect profits.

Although APMs create financial incentives for providers to improve patient engagement, little is known about whether hospitals in APMs are improving patient engagement during hospital care transitions, or whether improved patient engagement is an effective strategy for reducing readmission rates in the first place. If the latter is true but not the former, it suggests that APM policies are failing in their goal to improve patient-centered care, and that improving patient engagement is an overlooked strategy for succeeding in APMs. Moreover, enhancing the incentives for hospitals to improve patient engagement would be needed to reap the corresponding quality and cost benefits.

In this paper, we use four years of data from a national panel of hospitals to answer two questions: 1) are improvements in patient engagement during hospital care transitions associated with lower readmission rates, and 2) are APM-participating hospitals improving patient engagement? This study is one of the first national assessments of the impact of patient engagement on readmission rates. Results would help to evaluate current health reform policies that aim to improve readmission rates and patient-centered care.

Methods

Study Population

The study population included all non-federal, non-critical access, acute care hospitals in the continental United States that reported data to Hospital Compare during 2013-2017 and had at least one year of data for all study variables.

Study Measures: 30-Day All-Cause Readmission Rates and Patient Engagement

Hospital-level 30-day risk-standardized all-cause readmission rates were extracted for four annual measurement periods (ending June 30) from 2014 to 2017 from Hospital Compare. Patient engagement during hospital care transitions was measured at the hospital level using the 3-Item Care Transition Measure (3-item CTM), which was extracted for four annual measurement periods (ending December 31) from 2013 to 2016. The 3-Item CTM is a validated measure endorsed by the National Quality Forum (27, 28, 33-36). It is defined as the percentage of patients (Range 1-99%) who answer "strongly agree" to all three of the following questions on the H-CAHPS survey: (1) The hospital staff took my preferences and those of my family or caregiver into account in deciding what my health care needs would be when I left the hospital; (2) When I left the hospital, I had a good understanding of the things I was responsible for in managing my health; and (3) When I left the hospital, I clearly understood the purpose for taking each of my medications.

APM Participation

Under recent healthcare reform policies, hospital can participate in Alternative Payment Models (APMs) that provide incentives for hospitals to improve readmission rates. APMs include:

Accountable Care Organizations (ACOs), Medical Homes, and the Bundled Payment for Care Improvement (BPCI) program.

ACOs offer shared savings to participating hospitals if per-patient spending is lower than a targeted amount and certain quality measures are met. ACO participating hospitals have a strong incentive to improve patient engagement for two reasons: to lower healthcare spending and to improve performance on readmissions and related patient-centered measures (e.g. patient communication, incorporating patients into decision making processes, etc.). ACO start dates were obtained from Leavitt Partners on Medicare or commercial ACO participation (current as of 2016). The Leavitt Partners ACO database contains validated information on ACOs in the US and is regularly updated using data from multiple sources including press releases, government announcements, interviews, and public records. (37)

Medical Homes provide performance-based rewards for providers to reduce readmission rates, along with per member per month fees for care management. One of the core principles of Medical Homes is to coordinate acute care services.(38) For example, two common strategies that Medical Homes have used to meet this goal are care transition management programs (39) and physician-hospital integration (40). Therefore, hospitals that are affiliated with Medical Homes as part of their hospital-based ambulatory care practices may integrate ambulatory providers into inpatient care teams in order to facilitate patient engagement during patient care transitions; this practice has been shown to improve patient outcomes, especially for pharmacy-supported interventions during patient care transitions (41, 42). Hospital Medical Home participation was obtained from the 2013-2016 AHA survey; because start and end dates for Medical Home participation were unavailable, we assumed full calendar year participation. For 899 hospital-year observations that were missing data on Medical Home participation due to

AHA survey non-response, data was imputed using multiple imputations by chained equations. To avoid introducing bias, the imputation model included all variables in the main models as well as the following auxiliary variables: system ID if the hospital was in a system and hospital service code. (43) Based on best practices, we generated 10 imputed datasets which is roughly equal to the percentage of incomplete cases (9%). (44)

Finally, the BPCI program bundles inpatient and 30, 60, or 90 days of post-acute care services into a single "bundled payment" per episode of care. Hospitals participating in the program have an incentive to improve patient engagement in order to lower costs through reduced readmission rates. However, unlike the ACO and medical home programs, the BPCI program does not incorporate measures of patient-centered care or patient engagement into its program evaluation. Therefore, the effect of BPCI participation on patient engagement may be smaller than that of ACOs or medical homes. Quarterly participation in phase two of the BPCI program was obtained from the 2013-2016 Medicare BPCI public use file.

We created two measures of hospital participation in APMs. First, we calculated the portion of the calendar year (ending December 31) in which a hospital participated in *any* APM (either a Medicare or Commercial ACO, BPCI, and/or a Medical Home). Sensitivity analysis also tested the effect of participation in multiple programs on patient engagement. Second, because differences in APM design may have heterogeneous effects on patient engagement (e.g. ACOs have more quality measures related to patient-engagement than the BPCI program), we used a three-way interaction term between our measures of ACOs, Medical Home, and BPCI participation in our regression model, and calculated the marginal effect of participating in each APM type.

Control Variables

We extracted data on teaching status (major teaching status was defined as membership in the Council of Teaching Hospitals, and minor teaching status was defined as accreditation by the Accreditation Council for Graduate Medical Education), system membership, network membership, and ownership from the 2013-2015 American Hospital Association annual survey (2016 AHA data was not available at the time of the analysis), and data on number of beds, Medicaid Disproportionate Share Hospital (DSH) payments, case mix index, and urban/rural location from the 2013-2016 Medicare Impact file. Because data on these control variables are unlikely to change much over time, for hospitals that had at least one year of data, missing hospital-year observations were filled using the most recent prior year or future year of data if possible (n=2,815 hospital-year observations). Out of 3,969 hospitals that reported data to Hospital Compare in any year during the study period, 1,133 hospitals were missing at least one control variable for all years and were dropped from the analysis (Table 7). The vast majority of these hospitals (n=786) were missing control data from the Medicare Impact File.

Statistical Analysis

Our analysis utilized longitudinal data analysis on a panel of hospitals to understand relationships between our variables of interest while controlling for time and hospital-specific trends using mixed effects. For each of the models described below, we estimated mixed effects linear regression models using fixed effects for hospital controls and year, and hospital random effects. In addition, we used robust variance estimators to account for clustering by hospital referral region.

To answer our first research question, we tested whether improved patient engagement leads to reductions in readmission rates by regressing readmission rates on the level of patient engagement. To answer our second research question, we tested whether APM-participating hospitals improve patient engagement by regressing the level of patient engagement on APM participation. We did this twice, one for each measure of APM participation. For the model measuring participation by APM type, we calculated average marginal effects of participation in each type in order to estimate the impact of each type of APM on levels of patient engagement.

Two sensitivity analyses were run. Our first sensitivity analysis tested the sensitivity of our results to the number of APMs a hospital participated in in any given year, as participation in multiple APMs may strengthen the effect of APM participation on patient engagement. Our second sensitivity analysis tested the sensitivity of our main results to our treatment of missing variables by running the analyses only on the subset of hospitals without any missing data in all years of the study period.

Limitations

Compared to hospitals dropped due to missing data, hospitals in the sample were more likely to have a primary care department, be teaching hospitals, be in systems, be in networks, be non-profit, have more beds, have a higher case mix index and larger market share than hospitals not in the sample, which may limit generalizability (Table 7). We intentionally excluded federal hospitals and critical access hospitals from our analysis, due to differences in payment and incentive structures.

Second, a recent evaluation of the 3-item CTM found a correlation between responses to the 3-item CTM and a patient's medical history (sicker patients scored lower on the measure), as well

as heterogeneous effects of the 3-item CTM based on clinical severity (the 3-item CTM was associated with improved outcomes for patients undergoing cardiac angioplasty but not coronary artery bypass grafting) (28, 45). This has led to concerns that improvements in the 3-item CTM may not have the same effect on readmission rates across all patient populations, necessitating the need for risk adjustment in studies using the measure. In this study, we addressed this limitation by controlling for hospital case mix index, hospital characteristics, and hospital random effects. While it is possible that our results were influenced by unobserved patient characteristics that were omitted from the analysis, we think this is unlikely given that a recent study has found that APM-participating hospitals and non-participating hospitals serve similar patients (46) and that APM participation hospitals in our study sample did not differ significantly from non-participating hospitals in DSH percentage (Table 1).

Third, the measure of patient engagement used in this study was reported by CMS at the hospital-level. Therefore, we are unable to disaggregate the patient engagement measure by patient type or diagnoses. This limitation is particularly important to keep in mind when interpreting the association between BPCI participation and patient engagement because the BPCI program only covers specific service lines. In other words, the patient engagement measure measures patient engagement for all hospital discharges, whereas the BPCI program covers only a subset of patients; this limitation may bias our results towards the null if hospitals are selectively concentrating patient engagement measures in particular service lines. Relatedly, the measurement period for patient engagement (January to December) does not line up exactly with the measurement period for readmission rate (July to June), which may also bias our results towards the null.

Finally, while not a limitation, it is important to note that the scope of this study is limited. We use a validated measure of patient engagement during the hospital care transition to measure the patient perspective of care coordination quality at the point of discharge. However, there are other ways to measure the patient perspective of care coordination that could compliment the findings from this study, such as measuring patient engagement *following* a hospitalization, or in response to using specific care coordination interventions such as care coordinators or patient portals.

Results

This study sample included 9,960 hospital-year observations for 2,836 unique hospitals. Across all years, the unadjusted median readmission rate was 15% (standard deviation = 0.92) and the unadjusted median level of patient engagement was 51% (standard deviation = 6.21; Figure 2). The unadjusted average level of patient engagement was 50.8% for APM-participating hospitals before joining and 51.7% after joining, while the unadjusted median level of patient engagement was 50.6% for hospitals that never joined an APM. In our sample, assuming 310 hospitals missing data on Medical Home participation did not participate in a Medical Home, 51% of hospitals ever participated in an APM (n=1,451): 39% of hospitals participated in ACOs (n=1,093), 29% in Medical Homes (n=817,), 3% in BPCI (n=92) (Table 1). Hospitals participating in APMs differed significantly from hospitals that never participated in APMs in all control characteristics except DSH percentage: hospitals in APMs were more likely to have a primary care department, be urban, teaching, in a system, in a network, and non-profit; hospitals in APMs also had a larger number of beds and higher market share on average (Table 1).

In panel analysis, after adjusting for hospital-specific trends, characteristics, and year fixed effects, we found that each percentage point increase in patient engagement was associated with a -0.01 [95% confidence interval (CI): -0.02,-0.01] percentage point change in readmissions; this association was statistically significant (Table 2, Model 1). To put this finding in context, nationwide, if patient engagement levels were higher by 6.2 percentage points (or 1 standard deviation from the mean), roughly 27,164 additional hospital readmissions might be prevented in 2019, saving Medicare an estimated $404 million (47).

Adjusted analysis of the association between APM participation and patient suggestion suggests that APM participation did not have a statistically significant impact on patient engagement: full year APM participation was associated with a -0.12 (95% CI: -0.45, 0.21) percentage point change in the level of patient engagement (the percent of patients who reported "strongly agree" to all three of the 3-item CTM measures; Table 2, Model 2). When we examined participation by specific APM types, we found that BPCI participation led to a significant average marginal change in the level of patient engagement by -1.02 percentage points (95% CI: -1.68, -0.36; Figure 3). Whereas, the average marginal effect of ACO participation and Medical Home Participation on patient engagement was positive, but not statistically significant [0.18 percentage points (95% CI: -0.14, 0.52) and 0.13 percentage points (95% CI: -0.16, 0.41) respectively; Figure 3).

Sensitivity Analysis

Sensitivity analyses suggested that the marginal effect of participating in an additional APM on patient engagement was 0.13 percentage points (95% CI: -0.05, 0.31), this effect was not statistically significant (Table 8). The sensitivity analysis that used only hospital-year

observations with complete data for all variables did not yield different results from our main analysis; we found that each percentage point increase in patient engagement was associated with a significant -0.13 percentage point change in readmission rates (95% CI: -0.02, -0.01); and that APM participation is associated with a 0.30 percentage point change in patient engagement, though this effect was not statistically significant (95% CI: -0.01,0.62; Table 9).

Discussion

In this study, we asked whether patient engagement is associated with improved readmission rates, and whether patient engagement is improving under APMs. We found that greater patient engagement during hospital care transitions *was* associated with lower readmission rates, but that APM participation was *not* associated with improved patient engagement. Taken together, these finding suggest that APM participating hospitals may be overlooking a critical readmission reduction strategy that achieves the dual purposes of improving readmission rates and patient-centered care.

Our finding that patient engagement during hospital care transitions was associated with lower readmission rates is consistent with a growing body of evidence suggesting that investing in patient engagement may yield both cost and quality payoffs (26, 28-30, 48). These findings suggest that investing in patient engagement strategies during hospital care transitions may help hospitals succeed in reducing costs and improving patient-centered care, both priority areas under APMs (25).

However, our finding that APM participation was not associated with improvements in patient engagement during hospital care transitions suggests that APM model design may have failed to create strong enough incentives to promote patient-centered care in participating hospitals.

Despite the strong rhetoric surrounding the importance of patient-centered care and its role in enhancing care quality under APMs, actual Medicare policies may have not incorporated enough quality measures related to patient engagement in hospital settings in its APM programs. Specifically, in the Medicare Shared Savings Program (MSSP) only three of 31 quality metrics are related to patient engagement (provider communication, shared decision-making, and health promotion and education (49)) and of them, none are specific to patient engagement during hospital care transitions. Meanwhile, neither Medical Homes nor the BPCI program requires hospitals to meet any quality metrics to participate, and the upcoming BPCI advanced program only incorporates one measure relating to patient engagement (advanced directives), which is unrelated to care transitions.

We found that APM participation was not associated with improvements in patient engagement during hospital care transitions. This may be because APM-participating hospitals are engaging in other structural and process improvements to reduce costs, such as information exchange, patient selection, or upcoding (18, 50, 51). This explanation is supported by our finding that participation in the BPCI program has a negative effect on patient engagement, suggesting that patient engagement during hospital care transitions may actually be suffering at the expense of these other strategies. Another explanation is that APM participating hospitals are focusing efforts on improving patient-engagement *after* discharge (e.g. integrating providers into post-acute care settings or providing in-home follow ups). This may especially be true for Medical Homes, who may lack the influence and resources to improve hospital-based care coordination.

Our finding that APM participation is not associated with improvements in patient engagement during hospital care transitions seems to point against prior evidence suggesting that APM participation leads to hospital-level structural and process improvements that support care

coordination during care transitions (e.g. information sharing, care managers, performance-based contracts, and provider integration (52-58)). This may be because prior studies have used measures of the *provider* experience of care transitions, not the *patient* experience. Given empirical evidence suggesting that patient engagement during care transitions is an important predictor of better outcomes, it will be important not to lose sight of the patient experience when conducting future research and evaluating policies designed to improve care coordination. Future research should also examine how APM participation may be spurring improvements in other measures of patient experience of care coordination, such as engagement in electronic tools for patient communication (e.g. personal health records, patient-generated health information, and patient portals) and patient satisfaction measures.

Findings from this study have important implications for hospital leaders. Given that policy and delivery reform programs are increasingly focusing on the patient experience, improving patient engagement during hospital care transitions may be a "low hanging fruit" for participating hospitals to target that is an effective way to meet the dual goals of improve readmission rates and patient-centered care.

This study also has important policy implications for healthcare payment and delivery reform, especially in light of recent policy changes that are pushing for more patient-centered approaches to care, and accelerating hospital participation in payment and delivery reform programs. Given that a major objective of APMs is to improve patient-centered care, policy makers may wish to include more measures of patient engagement in evaluating APM performance (59). Specifically, policymakers may wish to add the 3-item CTM in its assessment of patient experience for Medicare ACO participants, include this measure in its quality metrics for the upcoming BPCI

Advanced program, and strengthen incentives to improve hospital performance under the patient centered medical home program.

Conclusion

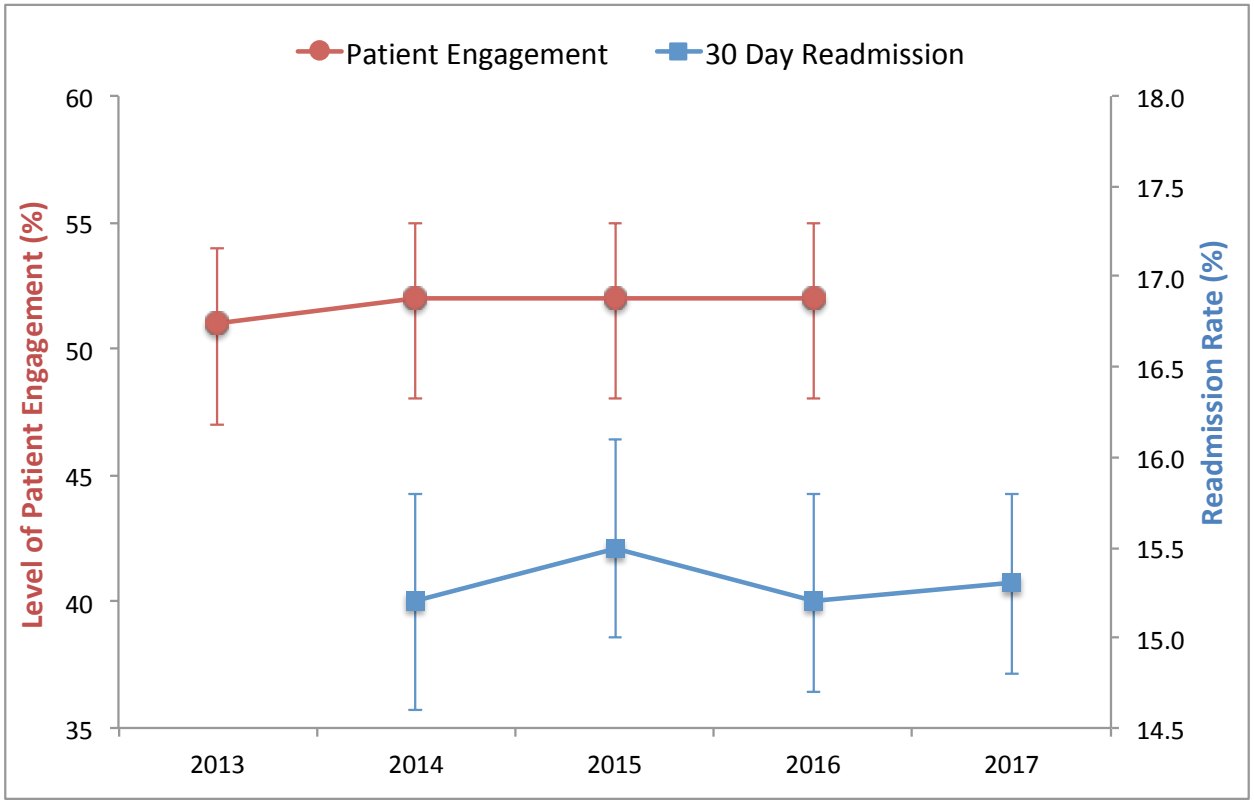
In this study, we sought to understand whether patient engagement during hospital care transitions is associated with improved readmissions, and whether hospitals participating in Alternative Payment Models are improving patient engagement. Our findings suggest that greater patient engagement is associated with lower readmission rates, but hospitals that join APMs are not improving patient engagement. This suggests that APM participating hospitals may be overlooking an important and effective patient-centered strategy to improving readmissions.

Table 1. Hospital Characteristics by APM Participation

Characteristics	All Hospitals (n=2,836)	Ever In APM[1] (n=1,451)	Never in APM[1] (n=1,385)
APM Participation (No. %)***			
Ever in APM	1,451 (51%)	1,451 (100%)	0 (0%)
Ever in ACO	1,093 (39%)	1,093 (75%)	N/A
Ever in Medical Home	817 (29%)	817 (56%)	N/A
Ever in BPCI	92 (3%)	92 (6%)	N/A
Never in APM	1,385 (49%)	0 (0%)	1,385 (100%)
Total[1]	2,836 (100%)	1,451 (100%)	1,385 (100%)
Has Primary Care Department[2] (No. %)***			
No	911 (36%)	326 (24%)	585 (51%)
Yes	1607 (64%)	1038 (76%)	569 (49%)
Total	2518 (100%)	1364 (100%)	1154 (100%)
Urban/Rural Classification (No. %)***			
Large Urban	1171 (41%)	763 (53%)	408 (29%)
Other Urban	953 (34%)	483 (33%)	470 (34%)
Rural	712 (25%)	205 (14%)	507 (37%)
Total	2836 (100%)	1451 (100%)	1385 (100%)
Teaching Hospital (No. %)***			
Non-teaching	1439 (51%)	552 (38%)	887 (64%)
Major (COTH)	232 (8%)	196 (14%)	36 (3%)
Minor (Med. School Affiliation)	1165 (41%)	703 (48%)	462 (33%)
Total	2836 (100%)	1451 (100%)	1385 (100%)
System Membership (No. %)***			
Not in a system	795 (28%)	291 (20%)	504 (36%)
In a system	2041 (72%)	1160 (80%)	881 (64%)
Total	2836 (100%)	1451 (100%)	1385 (100%)
Network Membership (No. %)***			
Not in a network	1616 (57%)	667 (46%)	949 (69%)
In a network	1220 (43%)	784 (54%)	436 (31%)
Total	2836 (100%)	1451 (100%)	1385 (100%)
Ownership (No. %)***			
Government	424 (15%)	162 (11%)	262 (19%)
Non-Profit	1850 (65%)	1184 (82%)	666 (48%)
For-Profit	562 (20%)	105 (7%)	457 (33%)
Total	2836 (100%)	1451 (100%)	1385 (100%)
Number of Beds (Mean (SD))***	203 (191)	253 (213)	151 (149)
DSH Percentage (Mean (SD))	0.29 (0.17)	0.28 (0.17)	0.29 (0.17)
Case Mix Index (Mean (SD))***	1.55 (0.32)	1.62 (0.29)	1.47 (0.34)
Hospital Marketshare (Mean (SD))***	1.49 (2.05)	1.76 (2.26)	1.22 (1.75)

Notes: [1]Assuming 310 hospitals missing data on Medical Home participation did not participate in the year that the data was missing. [2]Either owned or affiliated through a system or joint venture, not included in models. Hospital characteristics based on more recent available year of data per hospital. Difference between hospitals ever in APMs and never in APMs are statistically significant at ***p<0.001, **p<0.01, *p<0.05; Marketshare calculated as the percentage of beds in hospital system in hospital referral region.

Figure 2. Average Hospital 30-Day All Cause Readmission Rate and Patient Engagement by Year (2013-2017)



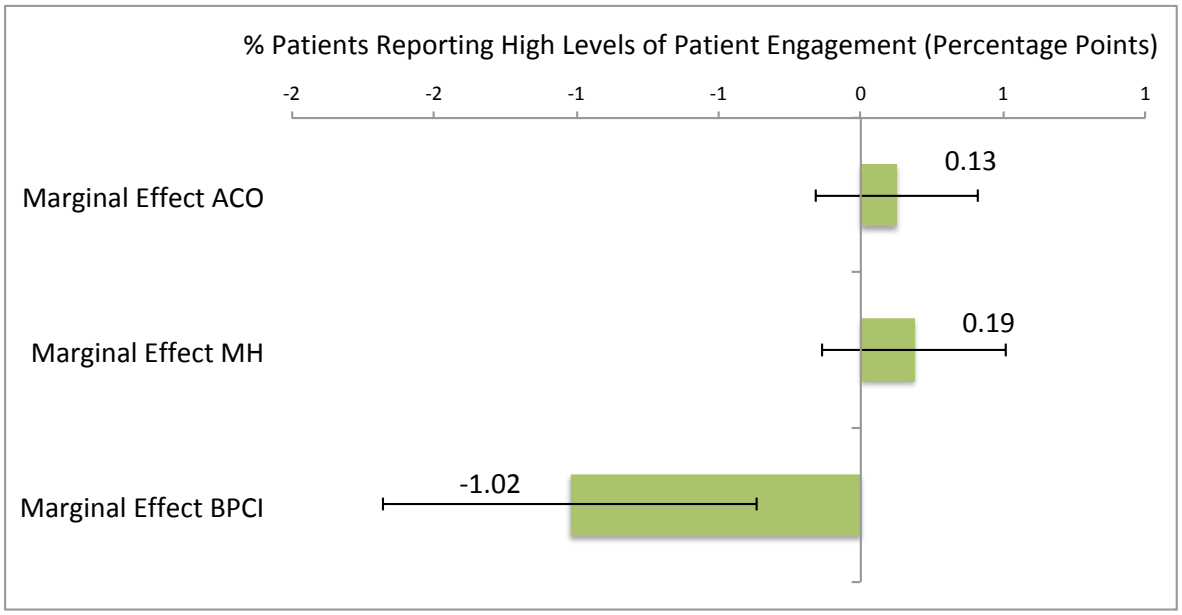
Note: Markers represent median, bars represent interquartile range

Table 2. Association between Patient Engagement, Readmissions, and Alternative Payment Models

Marginal Effects	(1) Patient Engagement and Readmission Rates	(2) APM Participation and Patient Engagement
Full Year APM Participation		-0.120
		[-0.450,0.209]
3-Item CTM	-0.012***	
	[-0.016,-0.008]	
Controls		
No. Beds	0.001***	0.001
	[0.001,0.001]	[-0.003,0.006]
Urban (Ref: Large Urban)		
Other Urban	-0.193***	0.390
	[-0.291,-0.096]	[-0.414,1.194]
Rural	-0.175**	0.474
	[-0.286,-0.064]	[-0.609,1.557]
DSH Percent	0.715***	3.103**
	[0.463,0.967]	[0.790,5.416]
Case Mix Index	-0.493***	0.822
	[-0.614,-0.372]	[-0.449,2.094]
Teaching (Ref: Non-Teaching)		
Major Teaching	-0.055	0.142
	[-0.109,0.000]	[-0.164,0.447]
Minor Teaching	0.398***	-0.480
	[0.270,0.527]	[-1.221,0.261]
System (Ref: Non-system)		
System Member	-0.027	-0.118
	[-0.069,0.015]	[-0.402,0.167]
Network (Ref: Non-network)		
Network Member	-0.022	-0.147
	[-0.070,0.025]	[-0.590,0.296]
Ownership (Ref: Government)		
Non-profit	-0.009	0.659
	[-0.095,0.077]	[-0.428,1.746]
For-profit	0.254***	-0.387
	[0.143,0.365]	[-1.914,1.141]
Marketshare (System HHI in HRR)	-0.044***	-0.115
	[-0.066,-0.021]	[-0.469,0.238]
Constant	16.392***	47.873***
	[16.068,16.716]	[45.530,50.215]
N (Hospital-Years)	9962.000	9962.000

Note: 95% confidence intervals in brackets. All models include hospital random effects and year fixed effects (not shown), and HRR clustered standard errors. *p<0.05, **p<0.01, ***p<0.001

Figure 3. Marginal Effects of APM Type Participation on Patient Engagement



Notes: Bars indicate marginal effects, lines indicate 95% confidence intervals; marginal effects based on mixed effects regression model regression patient engagement on types of APM participation; model includes hospital characteristics, year fixed effects, hospital random effects, and HRR clustered standard errors

Chapter 2. Hospital Health Information Exchange and Alternative Payment Models

Abstract

In this paper, we assess whether hospital participation in alternative payment models (APMs) is associated with greater engagement in health information exchange (HIE) along 4 dimensions: volume of patients for whom information is exchanged, diversity of information types, breadth of partner types, and depth of technical approach. We use pooled, cross-sectional analysis of data on US hospitals from 2014-2015. Data on APM participation came from Leavitt Partners data, Medicare public use files, and the American Hospital Association (AHA) Annual Survey. We used Medicare data to measure HIE volume for 798 hospitals attesting to stage 2 Meaningful Use and the AHA Information Technology Supplement to measure HIE diversity, breadth, and depth for 1730 hospitals. We used mixed-effects regression to estimate the association between participation in APMs and each dimension of HIE. We find that, compared with nonparticipating hospitals, full-year APM participation was associated with lower HIE volume (data were sent for 11 percentage points fewer discharges; $P = .003$), greater HIE diversity (of 4 data types, 0.3 more were transmitted; $P < .001$), greater HIE breadth (of 3 partner types, data were sent to 0.3 more; $P < .001$), and greater HIE depth (the odds of using a push and pull approach were 1.68 times greater; $P = .004$). Our finding that APM participation was associated with greater HIE diversity, breadth, and depth suggests that value-based payment may be spurring improvements in HIE infrastructure. However, our finding that APM participation is associated with lower HIE volume

suggests that there may be an incentive to focus HIE investments on a limited number of partners.

Introduction

Failures in information sharing between hospitals and post-acute care providers following hospital discharge can result in higher-cost, lower-quality care.(12, 60, 61) Electronic health information exchange (HIE) can improve the accessibility of information during hospital discharges, leading to cost savings and better outcomes.(13, 14) However, volume-based reimbursement does not create incentives for provider organizations to engage in HIE. (13, 14, 62-64) Medicare's alternative payment models (APMs) are expected to change this dynamic: By rewarding hospitals for improving the quality and cost-efficiency of care received across the care continuum, APMs create financial incentives for hospitals to engage in greater HIE.(65) However, even under APMs, significant barriers, such as lack of technical standards across EHR products, poor usability of HIE solutions, concerns about data security, and potential loss of profitable fee-for-service patients to competitors, may impede hospital pursuit of HIE. (13, 66)

If hospitals participating in APMs are not engaging in greater HIE, it is an ominous sign about the potential for HIE growth, as it suggests that even aligned financial incentives are not strong enough to overcome these barriers. It is therefore important to assess whether APM participation is associated with greater hospital HIE, and to do so in a way that reflects the multiple ways that HIE can generate value under APMs. Given that avoiding hospital readmissions is a core performance metric under APMs, improving HIE between hospitals and post-acute care providers is likely to be a prioritized use case for HIE.

The extent of hospital HIE engagement with post-acute care can be measured along 4 dimensions: volume, diversity, breadth, and depth.(67) Volume refers to the proportion of discharged patients for whom data are transmitted electronically. Diversity refers to the types of data that are transmitted electronically. Breadth refers to the types of trading partners to whom data are electronically transmitted. Finally, depth refers to the nature of the technical approach through which data are transmitted (i.e., pull and/or push).

Prior research on the association between APMs and HIE suggests that HIE is perceived as valuable to achieving financial rewards under APMs.(52, 68, 69) However, these studies have not systematically examined whether hospitals in APMs engage in greater HIE or whether HIE efforts focus specifically on supporting care coordination following discharges.

To assess whether participation in APMs is associated with greater HIE engagement with post-acute care providers along 4 dimensions (volume, diversity, breadth, and depth), we used mixed-effects regression analysis on data on US hospitals from 2014-2015. We define APM participation as the proportion of the calendar year that a hospital participated in at least 1 of the following programs: Medicare or commercial accountable care organizations (ACOs), the Medicare Bundled Payment for Care Improvement (BPCI) program, and any type of medical home. Results from this study are critical to informing policy efforts aimed at improving inter-organizational care coordination, a national policy priority. In particular, this work sheds light on challenges that may exist to improving inter-organizational care coordination through greater HIE under value-based incentives, such as those initiated under the Medicare Access and CHIP Reauthorization Act of 2015 (MACRA).

Methods

Setting and Data Sources

The study population includes all nonfederal acute care hospitals in the continental United States with HIE data for at least 1 year of the study period. Data for this study came from the Leavitt Partners ACO database (current as of 2016), 2014-2015 Medicare BPCI public use file, 2014-2015 American Hospital Association (AHA) annual survey, 2014-2015 Meaningful Use public use file, and 2017 Area Health Resource File.

Hospital Participation in Alternative Payment Models

Under MACRA, hospitals can participate in APMs that provide value-based incentives for hospitals to engage in HIE. Under APMs, hospitals are held accountable for the cost and quality of care provided by their outpatient partners. APMs include ACOs, the BPCI program, and medical homes. ACOs offer shared savings to participating hospitals if per-patient spending is lower than a targeted amount. The BPCI program bundles inpatient and outpatient services into single episodes of care. Lastly, hospitals can participate in medical homes as part of their hospital-based ambulatory care practices. Medical homes provide performance-based rewards, along with per-member per-month fees for care management.(70)

Measures

Independent variable: APM participation. We measured hospital participation in APMs by calculating the portion of the calendar year in which a hospital participated in any APM (a Medicare or commercial ACO, phase 2 of any BPCI model, and/or a medical home). ACO start dates for all ACOs formed as of 2016 were obtained from Leavitt Partners on Medicare or

commercial ACO participation. Quarterly participation in BPCI was obtained from the Medicare public use file. Medical home participation was obtained from the AHA survey; because start and end dates were unavailable, we assumed full calendar year participation.

Dependent variables: 4 dimensions of HIE. Drawing on a framework developed by Massetti and Zmud, we measured HIE engagement along 4 dimensions: volume, diversity, breadth, and depth. (67)

We measured volume as the proportion of discharged patients for whom summary of care records (SCRs) were sent electronically during a hospital's stage 2 Meaningful Use attestation period [for more on this measure and methodology, refer to Lin et al].. Data on this measure came from the Medicare Meaningful Use public use file.(13)

Following prior work (71, 72), we measured diversity as the number of data types (i.e., structured summary of care documents, radiology results, laboratory results, and medical history) that are routinely sent electronically by a hospital to ambulatory providers outside its system.

Breadth indicates how successful a hospital is at creating and maintaining connections with a variety of partners. Following prior work, we measured breadth as the number of partner types (ie, out-of-system ambulatory care providers, long-term care providers, and behavioral health providers) to which a hospital routinely sends structured summary of care documents.

We measured depth by assessing whether or not a hospital routinely transmits SCRs using either push or pull, or both approaches. Hospitals that used neither push nor pull (e.g., eFax, mail, or fax) were dropped from the analysis. Both push and pull approaches are useful for care coordination; however, the availability of both approaches is associated with greater provider

satisfaction and higher use. In the push approach, patient data are directly sent to another electronic system, whereas the pull approach aggregates data from multiple sources into a database that a provider can query. A hospital was considered as using a push approach if it used secure messaging to routinely transmit SCRs and a pull approach if it used patient portals or Epic's Care Everywhere HIE platform to routinely transmit SCRs. (A hospital was considered as using Care Everywhere if it reported using Epic as their primary inpatient EHR vendor and using a third party to routinely transmit SCRs.) Data on HIE diversity, breadth, and depth came from the AHA Information Technology Supplement.

Control variables. To control for potential confounding, we included controls that could be associated with both HIE engagement and APM participation: hospital size, urbanicity, teaching status, system membership, network membership, ownership, disproportionate share hospital (DSH) percentage, case mix index, critical access hospital status, and market share from the Annual AHA survey and the Medicare Impact File.(13, 14, 73, 74) To control for confounding that may arise from the number of trading partners, we included the number of skilled nursing facilities (SNFs), hospitals, and primary care providers (PCPs) in the county from the Area Health Resource File. Missing controls for a given year were imputed using forward, then backward, imputation. If no data were available on 1 or more control variables, the hospital was dropped.

Analytic Approach: Design and Statistical Analysis

Using hospital-year data from 2014-2015, we used mixed-effects models regressing each dimension of HIE engagement on APM participation and controls; we included hospital mixed effects to control for unobserved heterogeneity over time and across hospitals, year fixed effects

to control for temporal effects, and hospital-clustered standard errors to account for serial correlation. For our models of HIE volume, diversity, and breadth, we used linear regression; for our model of HIE depth, we used logistic regression.

Four sensitivity analyses were conducted: (1) To test whether our results were driven by concurrent participation in multiple APM types, we reran our analyses including the number of APM types in which a hospital participated; (2) To test whether participation in different APM types had different associations with HIE, we reran our analyses using a 3-way interaction term interacting participation in each of the 3 APM types in any given year; (3) To test whether using linear regression resulted in overestimated effect sizes, we reran the diversity and breadth models using negative binomial models; and (4) To test the sensitivity of our volume analysis to sample selection bias, we ran a Heckman model.

Results

Of 6101 hospitals in the AHA survey database from 2014-2015, we dropped 1537 non-continental federal hospitals. Of the remaining 4564 hospitals, 2233 had all control variables. Of those, 798 had at least 1 year of data on HIE volume (397 had 1 year and 401 had 2 years) and were included in our sample for HIE volume analysis. There were 1730 hospitals that had at least 1 year of data on HIE diversity and breadth (550 had 1 year and 1180 had 2 years) and were included in our sample for those analyses. There were 1427 hospitals that had at least 1 year of data on HIE depth and used push and/or pull to transmit SCRs electronically (662 had 1 year and 765 had 2 years); these hospitals were included in our sample for HIE depth analysis (Table 3).

Compared with hospitals that were missing HIE data, hospitals in our samples differed in important ways (Table 10). Hospitals in all 3 samples were more likely to participate in APMs.

They were also more likely to be not-for-profit; to be in hospital networks; to be larger, urban, teaching hospitals; to have a higher case mix index and higher market share; and to be in counties with more SNFs and PCPs.

Unadjusted bivariate analyses revealed that hospitals participating in APMs for any portion of the calendar year engaged in greater HIE than nonparticipating hospitals on all dimensions except volume (Figure 6). The average value of HIE volume was 53% among nonparticipating hospitals and 48% among participating hospitals. The average value of HIE diversity among nonparticipating hospitals was 2.4 data types and among participating hospitals was 3.1 data types. The average value of HIE breadth was 1.2 partner types among nonparticipating hospitals and 1.8 partner types among participating hospitals. Of the subsample of hospitals that used push and/or pull approaches, the percent of hospitals that used both push and pull approaches was 54% among nonparticipating hospitals and 69% among APM-participating hospitals.

After adjusting for controls and hospital-specific trends, full-year APM participation was associated with a –11 percentage point difference in HIE volume (21% fewer discharges than nonparticipating hospitals; $P = .001$), a 0.31 data type difference in HIE diversity (13% more data types than nonparticipating hospitals; $P < .001$), a 0.29 partner type difference in HIE breadth (24% more partner types than nonparticipating hospitals; $P < .001$), and greater HIE depth (the odds of using both push and pull approaches were 1.68 times greater in participating than nonparticipating hospitals; $P = .004$ (Figure 4 and Figure 6).

To make these results more interpretable, the adjusted predicted 2015 values for each HIE dimension for a common hospital type (medium-sized, urban, non-teaching, non-system, non-network, non-profit, non-critical access hospital, with DSH percentage, case mix index, and

market share held at their population means) are presented in Figure 5. The average predicted HIE volume for non-participating hospitals was 62% compared with 51% for hospitals participating for the full calendar year. The average predicted value for HIE diversity for nonparticipating hospitals was 2.8 data types compared with 3.1 data types for hospitals participating for the full calendar year. The adjusted predicted value for HIE breadth for nonparticipating hospitals was 1.4 partner types compared with 1.7 partner types for hospitals participating for the full calendar year. The probability of a nonparticipating hospital using both push and pull approaches versus only 1 approach was 72% compared with 80% among hospitals participating for the full calendar year.

Sensitivity Analysis

Results from our first sensitivity analyses suggest that our main results were not driven by concurrent participation in multiple APM types (Table 12). Results from our second sensitivity analysis suggest that the associations between APM participation types and dimensions of HIE access are similar to our main analysis (Figure 7). For ease of comparison, we used the model with 3-way interactions to estimate 95% CIs for each dimension of HIE for each pattern of APM participation. We then compared these CIs with that of our main analysis in Figure 2. Each of the CIs overlapped, suggesting that the associations between APM participation and dimensions of HIE did not significantly vary by APM participation type. Results from our third sensitivity analysis suggest that effect sizes from the analyses of HIE diversity and breadth may be slightly overestimated as a result of using linear models. However, because we were unable to run the negative binomial models using hospital mixed effects, we present the results of the negative binomial models in (Table 13**)**. Results from our final sensitivity analysis revealed evidence of moderate sample selection bias (athrho = –0.42; P = <.001). However, because results were

results and we were unable to control for hospital mixed effects in the Heckman model, we present these results in Table 14.

Discussion

Using national data on US hospitals from 2014-2015, we found that hospital APM participation was associated with greater HIE accessibility along 3 dimensions: diversity (number of transmitted data types), breadth (number of exchange partner types), and depth (number of technical approaches). However, APM participation had a negative association with HIE volume (percent of discharges in which an SCR was transmitted electronically). This finding suggests that challenges exist to increasing utilization of HIE for all patients under value-based reimbursement. There are several possible explanations. First, unlike other dimensions of HIE accessibility, greater HIE volume requires process and workflow changes that depend on clinician involvement. It may be that hospitals that participate in APMs increase the burden on clinicians to engage in multiple quality improvement initiatives at once, resulting in change fatigue and poorer performance on HIE volume. Change fatigue may be exacerbated by modifications to HIT structures, which may be occurring under APMs.(52, 68) Another explanation is that under APMs, hospitals focus HIE efforts on a few partner-specific connections, resulting in overall decreases in HIE, especially if HIE partners are not also those with whom hospitals share the highest volume of patients. On the other hand, APM-participating hospitals may be focusing HIE efforts on high-cost or complex patients to prevent readmissions. Future research should examine how the number of HIE partners changes under APMs, as well as patient-level factors that predict HIE use and the relationship to quality measures such as readmission rates.

Our finding that APM participation is associated with greater HIE diversity, breadth, and depth suggests that value-based payment reform may be spurring investments in HIE infrastructure as hospitals strive to achieve performance-based incentives through information-driven care coordination improvements for discharged patients.(75) However, given the limitations of our cross-sectional design, we were unable to say with strong certainty whether these associations reflect a causal relationship. It is possible that instead of APM participation driving changes in HIE, hospitals that choose to join APMs are also those that exchange data for fewer patients and have more mature HIE systems. It will be important to continue monitoring HIE activities in APM participating organizations in the future.

Our findings have important implications for policy makers. Prior efforts have primarily used direct incentives to promote HIE engagement through the Meaningful Use incentive program. With the passage of the 21st Century Cures Act, efforts have shifted to developing interoperable infrastructures and reducing information blocking. This study suggests that indirect incentives, through the form of value-based payments, may be an effective driver of HIE infrastructure that can overcome competitive forces that drive information blocking, at least among the hospital population included in this study.(74, 76)

Our findings suggest that even under value-based reimbursement, challenges may exist to improving HIE use. We find that APM participation is associated with worse HIE volume, which may be because hospitals restrict HIE efforts to a limited number of affiliated partners. This suggests that policies should focus on promoting HIE connections among all partners, not just those with whom hospitals have a strategic reason to share information. For example, medical home accreditation programs currently require engagement in HIE, but not a specific threshold of engagement. Specifying a threshold based on patient volume may incentivize hospitals to

improve overall interoperability rather than focus on partner-specific connections. Future studies should also examine whether APMs are promoting HIE connections with the most appropriate partners. Prior evidence suggests that although hospital HIE infrastructure is improving, these connections may not be serving the highest-volume partnerships.(77) On the other hand, APM-participating hospitals may be targeting HIE efforts toward high-cost or complex patients to prevent readmissions. Future research should also examine patient-level factors that predict HIE use.

Limitations

This study has important limitations. First, because measures of HIE were only available for 2014-2015, we were unable to use robust approaches to causal inference. Second, our measures of HIE dimensions do not take into account variation in other dimensions. For example, our measure of HIE breadth captures the number of partner types and not the number of partners within a single type with which a hospital shares information. It may be that hospitals only share information with a few partners of a specific type and we would not be able to detect this. Finally, because our analyses were restricted to hospitals with HIE data, hospitals in our sample differed from hospitals out of sample, limiting generalizability. Specifically, our sample for all models had a smaller proportion of smaller, rural, non-teaching, non-system, non-network, or for-profit hospitals than hospitals out of sample (Table 10). Therefore, our findings that APM participation is associated with lower HIE volume and higher HIE diversity, breadth, and depth may not apply to these hospitals. It will be important to assess whether our findings still hold for hospitals underrepresented in this study population.

Conclusion

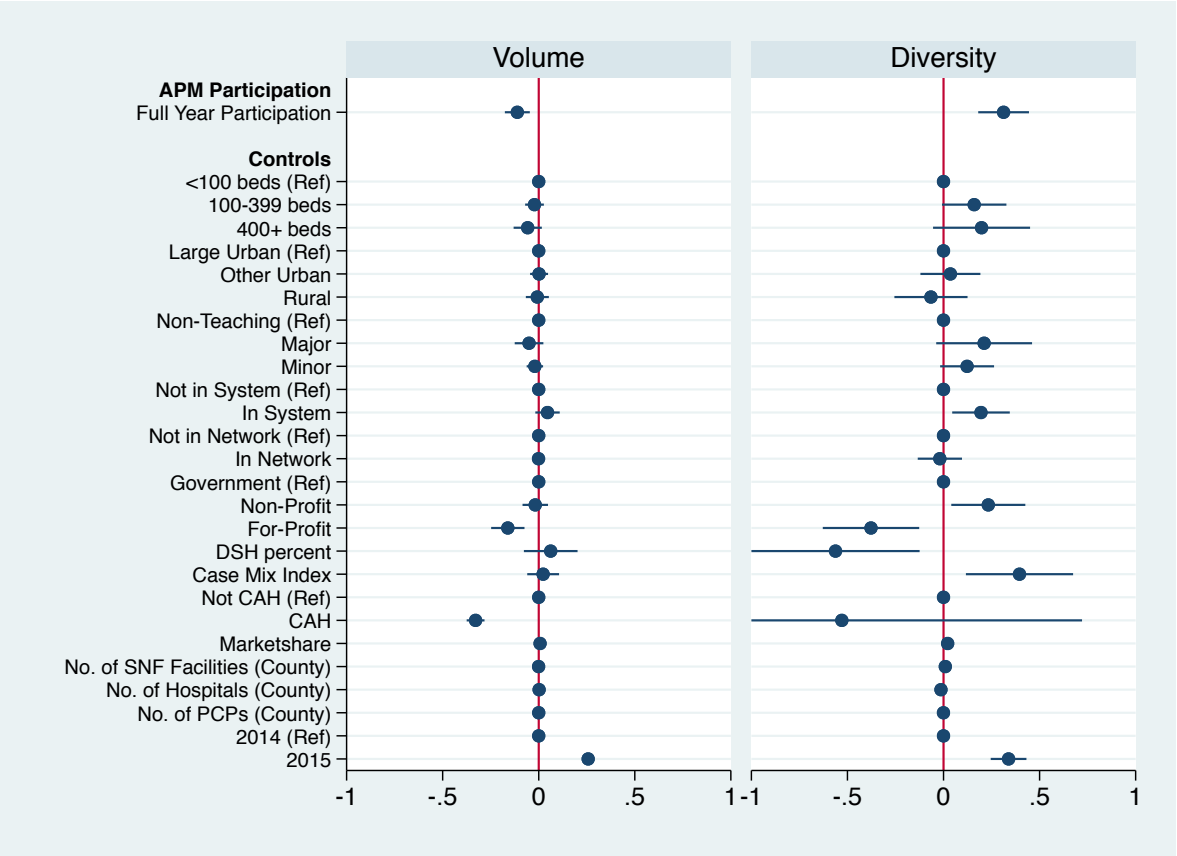
Our study assesses the association between APM participation and HIE engagement along 4 important dimensions: volume of data exchange, diversity of data types, breadth of partner types, and depth of exchange approach. We find that APM participation is associated with lower HIE volume, but greater HIE diversity, breadth, and depth. This finding suggests that under value-based reimbursement, indirect incentives may improve HIE infrastructure, but significant challenges to achieving high HIE volume remain and may require more targeted policy actions.

Table 3. Descriptive Statistics for Hospitals in HIE Samples

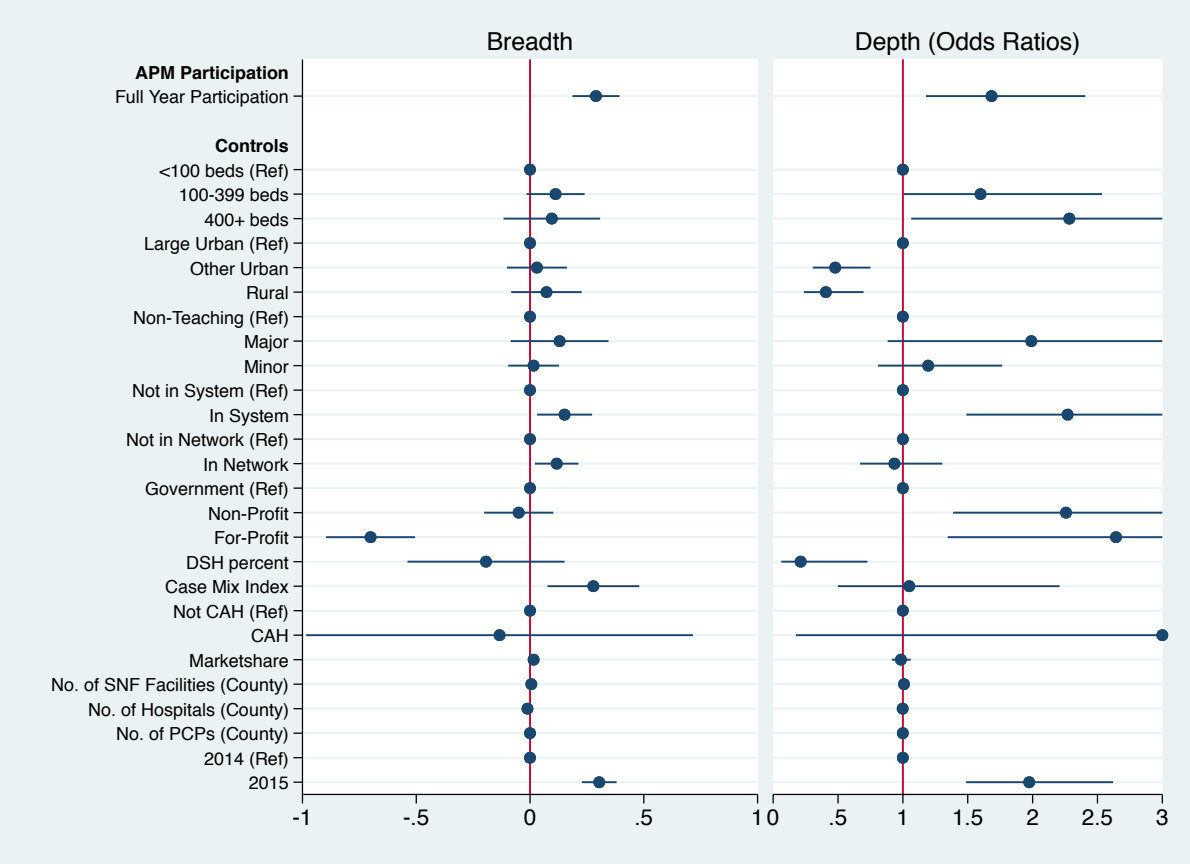
	Hospitals with Data on Volume (n=798)	Hospitals with Data on Diversity and Breadth (n=1730)	Hospitals with Data on Depth (n=1427)
	No. (%)	No. (%)	No. (%)
APM Participation			
Ever[1] in ACO	728 (91%)	696 (40%)	605 (42%)
Ever[1] in BPCI	152 (19%)	222 (13%)	196 (14%)
Ever[1] in Medical Home	390 (49%)	604 (35%)	540 (38%)
Any APM Participation			
Ever[1] Participated in any APM	766 (95.99%)	980 (56.65%)	856 (59.99%)
Never[1] Participated	32 (4.01%)	750 (43.35%)	571 (40.01%)
Size			
< 100 Beds	183 (22.93%)	576 (33.29%)	434 (30.41%)
100-399 beds	457 (57.27%)	903 (52.2%)	762 (53.4%)
400+ beds	158 (19.80%)	251 (14.51%)	231 (16.19%)
Urbanicity			
Large Urban	433 (54.26%)	732 (42.31%)	613 (42.96%)
Other Urban	249 (31.20%)	575 (33.24%)	486 (34.06%)
Rural	116 (14.54%)	423 (24.45%)	328 (22.99%)
Teaching			
Non-Teaching	300 (37.59%)	814 (47.05%)	636 (44.57%)
Major	111 (13.91%)	171 (9.88%)	158 (11.07%)
Minor	387 (48.50%)	745 (43.06%)	633 (44.36%)
System Membership			
Not in System	136 (17.04%)	520 (30.06%)	425 (29.78%)
In System	662 (82.96%)	1210 (69.94%)	1002 (70.22%)
Ownership			
Government	80 (10.03%)	243 (14.05%)	191 (13.38%)
Non-Profit	659 (82.58%)	1218 (70.4%)	1040 (72.88%)
For-Profit	59 (7.39%)	269 (15.55%)	196 (13.74%)

Notes: [1]Ever/Never Participation as of 2016.

Figure 4. Regression Results, Adjusted Association between APM participation and Dimensions of HIE Engagement

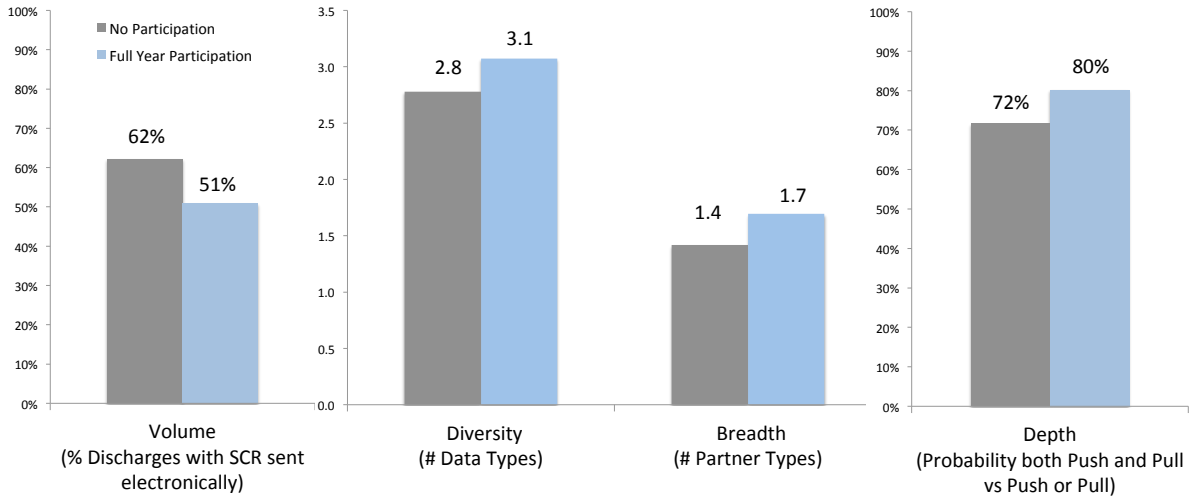


[Continued on Next Page]



Note: All models include hospital mixed effects and year fixed effects. Circles indicate effect size estimate, lines indicate 95% confidence intervals; depth analysis presented as odds ratios

Figure 5. 2015 Predicted Performance on Four Dimensions of Hospital HIE Engagement by APM Participation



Notes: Based on 2015 predicted values for medium sized, urban, non-teaching, non-system, non-network, non-profit non-critical access hospitals with continuous variables held at their population means. 2015 predictions based on mixed effects regression models controlling for hospital mixed effects, year fixed effects, and the following hospital characteristics: number of beds, urban/rural classification, teaching status, system membership, network membership, ownership, DSH percentage, case mix index, and marketshare.

Chapter 3. The Impact of the Bundled Payment for Care Improvement (BPCI) Program on Hospital Post-Acute Care Referral Networks and Quality of Skilled Nursing Facilities

Abstract

Hospitals may be better able to control the cost and quality of post-acute care if discharges are concentrated among fewer skilled nursing facilities (SNF). Model 2 of Medicare's Bundled Payment for Care Improvement (BPCI) program pays hospitals a targeted price per episode to cover both inpatient and 30, 60, or 90 days of post-acute care services. Hospitals in the BPCI program may attempt to reduce costs by concentrating patient referrals to a smaller number of SNF partners. In this study, we use national longitudinal data from 2009-2015 to understand whether hospital-SNF referral patterns change significantly after a hospital joins the BPCI program; and what kinds of SNFs receive a larger share of patient discharges after a hospital-partner joins the BPCI program. We found that BPCI participation led to a decrease in the number of SNF referrals and no change in the concentration of SNF referrals or number of SNF partners. We also found that a larger percentage of patient referrals were sent to SNFs with a higher quality rating after a hospital joins the BPCI program. Collectively, these findings suggest that the BPCI program may be leading to improvements in overall quality of post-acute care, without a significant change in hospital-SNF referral patterns.

Introduction

In an effort to improve the value of healthcare for Medicare beneficiaries, recent payment reforms from the Centers for Medicare & Medicaid Services (CMS) hold hospitals responsible for the cost and quality of care provided both during and after a hospitalization. Specifically, the Bundled Payment for Care Improvement (BPCI) extends hospital accountability according to alternative models. Under Model 2, hospitals receive a target price for a care episode covering all hospital, physician, and post-acute services within 30, 60, or 90 of discharge (5). With discharges to skilled nursing facilities (SNFs) accounting for nearly 20% of Medicare inpatient discharges (78) and nearly a quarter of SNF-discharged patients being readmitted within 30 days after their index admission (79), participating hospitals may re-examine their relationships with their SNF partners as a strategy to control their episode costs.

For instance, care coordination activities (e.g. electronic information exchange, visiting clinical care teams, designated patient care coordinators) have been shown to be effective at reducing readmission rates for SNF-discharged patients (18). One way that participating hospitals could improve care coordination activities with their SNF partners would be to concentrate their referrals among fewer SNFs (80). **To this end, hospitals may attempt to change patterns of hospital-SNF referrals by influencing patients' choice of receiving SNF**. For example, many hospitals provide patients a brochure with a list of "preferred SNFs" at discharge. These hospitals may have formal committees dedicated to procuring and managing data from these specific SNFs, and some preferred SNFs may even agree to adhere to specific performance standards (e.g. length of stay, readmission rates) in exchange for being marketed as a "preferred SNF" (18, 19). Although there may be significant advantages to concentrating patient referrals to a selected group of SNF partners (i.e. "narrowing" the referral network), CMS prohibits hospitals

from restricting patient choice of receiving SNFs in response to the much-criticized limited provider networks of Health Management Organizations (HMO) in the late 1990's. In actuality, restricted networks may be a double-edged sword: on the one hand, quality of care may suffer if patients are locked into poorer performing networks, on the other hand, narrowing networks may lead to overall improvements in the cost and quality of post-acute care if poorer quality SNFs are "pruned" or left out of preferred networks (81).

A prior study suggests that, despite CMS's rule prohibiting them from influencing patient choice of receiving SNFs, many hospitals are attempting to change SNF referral networks by referring patients to publically available data on SNF quality or actively promoting SNFs in their preferred networks (18). However it is currently unknown whether hospitals in the BPCI program are able to cause significant changes to actual hospital-SNF referral patterns and whether these changes are likely to improve SNF quality. Filling this knowledge gap is important to understanding the impact of payment reform on networks of health services delivery, and will contribute to the growing body of literature examining how the structure of referral networks influence healthcare quality (82-84).

To understand whether hospitals participating in the BPCI program are changing SNF referral patterns, and what kinds of SNFs receive a larger share of patients from BPCI-participating hospitals, we use national claims data from 2009-2015 on Medicare patients undergoing joint-replacement, a condition that is highly sensitive to post-acute care quality. First, we assessed whether SNF discharge patterns change after a hospital participates in the BPCI program for joint replacement, one of the most popular and effective BPCI programs. Then, we examine changes in SNF quality after BPCI participation.

Methods

Data source and study population

For our study, we analyzed inpatient and outpatient Medicare claims from a random 20% national sample of beneficiaries over years 2009 through 2015. We began by identifying patients in our sample who were discharged directly to a SNF following an admission for joint replacement [diagnosis-related group (DRG) 469 (major joint replacement or reattachment of lower extremity with major complications or comorbidities) or DRG 470 (major joint replacement or reattachment of lower extremity without major complications or comorbidities)] at an acute care, non-critical access hospital. To be eligible for inclusion, we required beneficiaries to be enrolled in Parts A and B of fee-for-service Medicare for the 12 months prior to their index admission and 90 days post-discharge (or until death), and be residents of the continental US. Following prior work, we excluded beneficiaries with a SNF claim within the three months prior to the index admission because a beneficiary's previous stay may influence a hospital's future choice of SNF (80). We also excluded re-hospitalizations that occurred within 30-days of the index admission.

Main Outcomes

Next, we counted the number of patients shared between every hospital-SNF pair per year over our study period. From this, we created a bipartite (or two-mode) hospital-SNF network for each hospital. Briefly, networks are a collection of points (called nodes) connected together in pairs by lines (referred to as edges). In bipartite networks, nodes of the same class are never directly connected to each other. Because our research question centered on relationships between hospitals and SNFs, we created a unipartite projection of the bipartite networks such that

hospitals were connected directly to SNFs and the edges between them were weighted by the number of shared patients. From these network data, we calculated three main outcomes at the hospital-year level: the number of total direct discharges to SNF partners, the number of SNF partners, and the concentration of SNF referrals [as measured by the Herfindahl-Hirschman Index (HHI), which characterizes the number of discharges per SNF partner on a scale of 0 to 1]. We chose these measures because they are directly comparable to other network measures used in prior literature examining hospital-SNF referral relationships (80), and because they can be more easily interpreted by policymakers and clinicians.

Four measures of SNF quality were extracted from Nursing Home Compare (2009-2015): survey rating, outcomes (quality) rating, staffing rating, and registered nurse staffing rating. These measures are based on the five-star rating developed by Nursing Home Compare, which ranks hospitals on a scale of 1 to 5 based on a variety of different quality metrics (85). The survey rating measure is based on the number, scope, and severity of deficiencies identified by facility inspections over 36 months (e.g., the 2009 measure was collected from 2006 to 2009) and adjusted for the number of inspections. The outcomes rating measure is based on 10 risk-adjusted outcome measures endorsed by the National Quality Forum (e.g., percent of short-term stay residents with pressure ulcers, percent of long-term stay residents with urinary tract infections). These measures are reported to CMS quarterly; for this study, we calculated an average for each measure per calendar year. The staffing rating and nurse staffing measures are based on the ratio of nursing hours per resident (nurse and registered nursing hours respectively), adjusted for patients' clinical severity. These measures are reported to CMS quarterly; for this study, we calculated an average for each measure per calendar year. (See Appendix Exhibit C 1 for full measure details.)

Main independent variable

Our main independent variable was the percent of the calendar year during which a hospital participated in Model 2 of the BPCI program for joint replacement (major joint replacement of the upper extremity, major joint replacement of the lower extremity, or double joint replacement of the lower extremity). BPCI participation was measured using a continuous variable to account for hospital enrollment on a quarterly basis and hospital exits from the program.

Hospital control characteristics

Hospital control characteristics included whether the hospital offered skilled nursing care (via hospital, health system, or joint venture), teaching status (major teaching status was defined as membership in the Council of Teaching Hospitals, and minor teaching status was defined as accreditation by the Accreditation Council for Graduate Medical Education), system membership, and ownership (non-profit, for-profit, or government) from the American Hospital Association Annual Survey (2009-2015), ACO participation a Medicare, Medicaid, or commercial ACO from the Leavitt Partner's ACO database, and data on number of beds, market share, Medicaid Disproportionate Share Hospital (DSH) payments, case-mix, and urbanicity from the Medicare Impact File (2009-2015). Hospital-county characteristics included the number of SNFs and the number of SNF beds from the Area Health Resource File (2010-2015). Because these characteristics are unlikely to change much from year to year, data from previous years and then future years was used to fill in missing control characteristics.

Statistical analysis

To understand whether hospitals participating in the BPCI program are changing SNF referral patterns, we ran three linear regression models. The first model regressed the number of SNF discharges on BPCI participation. The second model regressed the number of SNF referral partners on BPCI participation, and the third model regressed hospital-level SNF referral concentration on BPCI participation, controlling for the number of SNF-discharges. In the second and third models, we included a control for the number of total discharges to SNF partners to account for the impact of patient volume on these two network measures. All models included hospital control characteristics (e.g. case mix index to control for patient need, DSH percent to control for patient resources, etc.), year fixed effects, and hospital fixed effects.

In order to understand what kinds of SNFs receive a larger share of patients from hospitals, we conducted analyses on our discharge-level dataset. We estimated Poisson regression models regressing the quality of a receiving SNF on the BPCI participation status of the discharging hospital at the time of patient discharge, while controlling for hospital fixed effects, hospital characteristics, and year fixed effects. We ran four models, one for each measure of SNF quality. Each model was weighted by the inverse of the number of dischargers per hospital to account for duplicate observations per hospital.

We conducted three sensitivity analyses. First, to test the sensitivity of our results to our treatment of missing data, we repeated our analyses on the subset of observations with full data (dropping the variables for percent Medicare/Medicaid SNF residents and whether the SNF is a chain because this data was unavailable for 2013-2015). Second, because linear regression assumes an unbounded range for the dependent variable, yet our measure of referral

concentration is bounded between 0 and 1, we used a fractional response regression with hospital-clustered standard errors and hospital referral region (HRR) fixed effects. Because we were unable to include hospital fixed effects in the fractional response regression model, we present the results from the fixed effects linear regression as our main analysis. Finally, because some hospitals may have less control over SNF referral networks for patients discharged to SNFs outside their areas (e.g. large referral centers may receive more out-of-town patients who choose to be discharged to SNFs closer to home), we dropped 6,724 hospital-SNF pairs that were not in the same HRR, re-calculated our measure of SNF referral concentration and number of SNF partner measures, and repeated our analyses.

Limitations

Findings from our study should be interpreted with several limitations in mind. First the generalizability of our results is limited to Medicare joint-replacement patients only and may not generalize to commercially-insured patients or other BPCI programs. However, given that Medicare is leading the movement behind bundled payments and that the BPCI program for joint-replacement has been one of the most populous (close to 60% of BPCI-participating hospitals participate in the joint-replacement program), findings from this study still have important implications for the future of BPCI and commercial bundled payment programs more broadly.

Second, missing data on hospital and SNF characteristics may also limit the generalizability our results. Compared to the 411 hospitals out of sample, hospitals in sample were more likely to be in BPCI, more likely to offer SNF services in the hospital, more likely to be rural, and on average had fewer beds, healthier case mix, and came from counties with fewer SNF beds (Table

15). Compared to SNFs out of sample, SNFs in sample were less likely to be in an ACO, more likely to be in a chain, less likely to be government owned, and, on average, had more beds, a higher occupancy rate, fewer Medicare residents and more Medicaid residents (Table 15). However, given the relatively small number hospitals and SNFs dropped due to missing data (n=411 and 2,362; or 15% and 18%, respectively), hospitals and SNFs dropped due to missing data are not likely to differ much from hospitals and SNFs in the U.S. as a whole.

Another important limitation is that our study examines all patients undergoing joint replacement, regardless of the presence of comorbid conditions. It may be that certain hospitals receive a disproportionate share of patients with comorbid conditions that would result in a larger number of patients discharged directly to SNF. While this study attempts to control for the severity of the patient population using hospital fixed effects, it does not directly control for patient characteristics, which may impact SNF choice.

Finally, while not a limitation, it is important to note that our study uses claims data to understand how *actual* hospital-SNF referrals patterns change as a result of BPCI participation; however, we are unable to speak about the *intended* changes in referral networks patterns. In other words, hospitals in the BPCI program may *intend* on increasing referrals to certain preferred SNF partners, but they may not be able to do so due to legal restrictions, patient preference, or individual provider preferences.

Results

The original claims data used for this study contained data on 159,775 discharges for 146,074 unique beneficiaries from 2,765 hospitals to 12,773 SNFS from 2009-2015. Of the 2,765 hospitals, 2,727 (99%) hospitals were successfully matched to AHA data on hospital

characteristics and 2,354 (85%) of hospitals had data on all hospital control variables; these hospitals comprised our analytic sample for the hospital-level analysis, representing 14,295 hospital-year observations (Appendix Exhibit C 2). Of these hospitals, 235 ever participated in model 2 of the BPCI program for joint replacement; 5 started participating in 2013, 55 started participating in 2014, and 175 started participating in 2015.

For the SNF quality analysis, 11,767 (92%) SNFs of the 12,773 in the original claims data were successfully matched to the Nursing Home Compare database, 10,903 (85%) of these SNFs belonged to hospital-SNFs pairs where the hospital had no missing data. An additional 520 SNFs were dropped because they were missing data on SNF quality; consequently 8 additional hospitals were dropped because all of their partnering SNFs were missing data. The final analytic dataset for the SNF quality analysis contained observations on 139,452 discharges for 127,898 unique beneficiaries discharged from 2,346 hospitals to 10,383 (88%) SNFs. (Appendix Exhibit C 2)

Hospitals that joined the BPCI program differed significantly from hospitals that never joined the BPCI program in important ways. Hospitals that joined the BPCI program were significantly more likely to also be in an ACO. They were more likely to offer SNF services through their healthcare system or a joint venture, be in a large urban area, be a teaching hospital, and be non-profit. On average, they also had more beds, a lower DSH percentage, a sicker case mix, and come from counties with more SNF facilities and more SNF beds. (Table 4) They also had different SNF referral patterns. On average, hospitals that joined the BPCI program discharged 17 patients per year to SNFs prior to joining the program, and 16 patients to SNFs after joining the program, while hospitals that never joined the BPCI program discharged 10 patients to SNFs per year. On a scale from 0 to 1, where 0 signifies that all patients were discharged in equal

proportion to all SNF partners, and 1 signifies that all patients were discharged to a single SNF partner, the average SNF referral concentration for hospitals that joined the BPCI program was 0.36 prior to joining the program, and 0.34 after joining the program; and 0.47 for hospitals that never joined the BPCI program. Finally, on average, hospitals that joined the BPCI program had 7 SNF partners prior to joining the program, and 8 SNF partners after joining the program, while hospitals that never joined the BPCI program had 5 SNF partners.

In hospital-level analysis, we found that the number of SNF discharges per year decreased by -3.39 patients after hospitals joined the BPCI program, or 19% of the pre-BPCI average; this effect was statistically significant [95% Confidence Interval (CI): -4.72, -2.06]. We found that the number of SNF partners changed by 0.05 SNFs after hospitals joined the BPCI program, or 0.6%; this effect was also not statistically significant (95% CI:-0.38,0.48; Table 5, Column 3). We also found that SNF referral concentration dropped by -0.02 after hospitals joined the BPCI program, or 6% of the pre-BPCI average, however this effect was not statistically significant (95% CI:-0.07,0.03; Table 5, Column 2).

Analysis of SNF quality revealed that patients discharged from BPCI-participating hospitals were discharged to SNFs with higher quality. Specifically, we found that, on average, BPCI participation led to changes in a receiving SNF's average quality ratings by 0.04 star for the survey rating (95% CI:-0.03, 0.11; Table 6, Column 1), 0.20 star for the outcomes rating (95% CI:0.14, 0.26; Table 6, Column 2), -0.10 star for the staffing rating (95% CI:-0.07, 0.04; Table 6, Column 3), and 0.04 star for the RN staffing rating (95% CI:-0.09, 0.02; Table 6, Column 4).

Sensitivity analysis using only the subset of observations with non-missing data suggests that our analyses were not significantly impacted by the way we handled missing data, our main

coefficients were similar in both effect size and statistical significance (Table 16). Results from the second sensitivity analysis where we used a fractional response model to analyze hospital referral concentration was consistent with that of our main analysis (Table 17). Similarly, the results from the sensitivity analysis where we dropped hospital-SNF pairs not in the same HRR were consistent with the results from our main analysis, with one exception. The association between BPCI participation and survey rating was statistically significant: on average, BPCI participation was associated with a 0.08 star change in a receiving SNF's survey rating (95% CI: 0.01, 0.16; Table 18).

Discussion

In this national study on hospital-SNF referral patterns for BPCI participating hospitals, we found little evidence that patterns of SNF-referrals change after hospitals join the BPCI program. After BPCI participation, the number of patients discharged to SNFs per hospital went down, but we found no change in the number of SNF partners or the concentration of SNF referrals. However, we did find that BPCI participating hospitals sent patients to higher quality SNFs. Taken together, this suggests that instead of patients being referred to higher quality SNFs, it may be that SNFs in BPCI-participating hospital referral networks are improving the quality of care. This explanation is supported by prior evidence suggesting that patients discharged from BPCI-participating hospitals have better post-acute care outcomes than non-participating hospitals (86), and should be further examined in future research.

We also found that the BPCI program was associated with a significant decrease in the number of patients discharged to SNFs. This finding is consistent with a recent studies suggesting that BPCI-participating hospitals are reducing SNF utilization in an effort to control costs (19, 20,

86). However, our finding that SNF referral concentration did not change seems to point against qualitative evidence suggesting that participating hospitals are using preferred networks (19). Similarly, we did not find evidence that the BPCI program is associated with a pruning of SNF partners, or a fewer number of SNF partners. These findings either suggest that narrowing SNF networks is not a widely used strategy for BPCI-participating hospitals or attempts to narrow SNF networks (such as through preferred networks) are not resulting in substantial changes in referral patterns. If the latter is true, it may speak to some of the challenges inherent in establishing these networks, such as legal restrictions, patient or provider preferences, or limited SNF options (87).

It is also interesting that we found that BPCI participation was significantly associated with the outcome rating and not the staffing ratings. There are several possible explanations for this finding. First, SNFs in BPCI-participating hospital networks may be findings ways to improve quality without increasing staffing. Another possible explanation is that hospital involvement in SNFs is increasing through improved care coordination and post-acute care follow-up, leading to better outcomes but no difference in staffing. Another explanation is that SNF-discharged patients are being discharged in better condition than they were before the hospital joined the BPCI program, leading to better outcomes. This may certainly be the case if BPCI participating hospitals are improving the quality of care during the index hospitalization through better adherence to evidence-based protocols as prior evidence suggests (88).

Policy Implications

This study has important implications for policies that aim to improve the quality of post-acute care using bundled payment programs. Specifically, our findings suggest that policy

interventions that target hospitals may also be an effective way to improve the quality of post-acute care. Hospitals have long been influential actors in the US healthcare system, and their influence is likely to increase as policies continue to push for more integrated approaches to care delivery (89). This study points to the increasing role that hospitals are playing in influencing the quality of care delivered outside of its four walls and the role that payment reform can play in accelerating this trend.

This work also has implications for hospitals involved in bundled payment programs. Specifically, we found evidence that hospital-SNF referral patterns do not change, despite strong qualitative evidence of hospitals' *intention* to increase discharges to "networks of preferred SNFs" (19). This finding speaks to the challenges that exist in systematically changing the way that patients are referred to SNFs (87) and suggests that additional research may be necessary to understand how best to help patients and caregivers choose high quality post-acute care facilities after a hospital discharge.

Conclusion

In this national study on the impact of the Bundled Payment for Care Improvement (BPCI) program on hospital-SNF referral patterns, we found that BPCI participation led to an overall decrease in SNF utilization, no change in the concentration or number of SNF partners, and an increase in the quality of SNFs. Taken together, this study suggests the BPCI program may be leading to improvements in overall quality of post-acute care, without significant changes in hospital-SNF referral patterns.

Table 4. Hospital Characteristics by BPCI Participation

Characteristics	All Hospitals in Sample (n=2,354)	Hospitals In BPCI (n=235)	Hospitals Never in BPCI (n=2119)
Ever in ACO (No. %)***			
Never in ACO	1477 (63%)	80 (34%)	1397 (66%)
Ever in ACO	877 (37%)	155 (66%)	722 (34%)
Total	2354 (100%)	235 (100%)	2119 (100%)
Hospital offers SNF Services (No. %)			
In Hospital	386 (16%)	33 (14%)	353 (17%)
In System**	362 (15%)	67 (29%)	295 (14%)
Through Joint Venture***	68 (3%)	16 (7%)	52 (2%)
Urban/Rural Classification (No. %)***			
Large Urban	964 (41%)	151 (64%)	813 (38%)
Other Urban	816 (35%)	73 (31%)	743 (35%)
Rural	574 (24%)	11 (5%)	563 (27%)
Total	2354 (100%)	235 (100%)	2119 (100%)
Teaching Hospital (No. %)***			
Non-teaching	1169 (50%)	57 (24%)	1112 (52%)
Major (COTH)	200 (9%)	32 (14%)	168 (8%)
Minor (Med. School Affiliation)	985 (42%)	146 (62%)	839 (40%)
Total	2354 (100%)	235 (100%)	2119 (100%)
System Membership (No. %)			
Not in a system	562 (24%)	32 (14%)	530 (25%)
In a system	1792 (76%)	203 (86%)	1589 (75%)
Total	2354 (100%)	235 (100%)	2119 (100%)
Ownership (No. %)*			
Government	268 (11%)	8 (3%)	260 (12%)
Non-Profit	1559 (66%)	183 (78%)	1376 (65%)
For-Profit	527 (22%)	44 (19%)	483 (23%)
Total	2354 (100%)	235 (100%)	2119 (100%)
Number of Beds in 100s (Mean (SD))***	2 (2)	3 (2)	2 (2)
Hospital Marketshare (Mean (SD))	1.6 (2.11)	1.94 (2.34)	1.56 (2.08)
DSH Percentage (Mean (SD))*	0.27 (0.15)	0.24 (0.13)	0.27 (0.15)
Case Mix Index (Mean (SD))***	1.54 (0.29)	1.64 (0.25)	1.53 (0.29)
No. SNF Facilities in County (Mean (SD))***	22.51 (31.97)	38.23 (48.17)	20.77 (29.14)
No. SNF Beds in County in 100s (Mean (SD))***	30.04 (31.97)	54.8 (79.73)	27.3 (45.42)

Notes: Difference between hospitals in and not in the BPCI program significant at *p<0.05, **p<0.01, ***p<0.001; statistics based on most recent year of data per hospital

Table 5. Adjusted Regression Results: BPCI Participation and SNF Referral Pattern

Marginal Effects	(1) No. Discharges	(2) Concentration	(3) No. SNF
BPCI Participation for Joint Replacement	-1.69***	-0.01	-0.12
	[-2.53,-0.85]	[-0.04,0.03]	[-0.39,0.15]
Controls			
Number of SNF Discharges		-0.01***	0.24***
		[-0.01,-0.01]	[0.24,0.25]
ACO Participation	-0.20	0.00	-0.08
	[-0.55,0.15]	[-0.01,0.02]	[-0.19,0.04]
Hospital Offers Skilled Nursing care			
Through Hospital	0.18	0.01	-0.02
	[-0.27,0.62]	[-0.01,0.03]	[-0.17,0.12]
Through System	0.06	-0.01	0.10
	[-0.38,0.51]	[-0.03,0.00]	[-0.04,0.24]
Through Joint Venture	-1.40**	0.01	-0.23
	[-2.30,-0.51]	[-0.02,0.05]	[-0.52,0.05]
Teaching (Ref: Non-Teaching)			
Major Teaching	0.30	0.01	-0.08
	[-0.13,0.72]	[-0.01,0.03]	[-0.22,0.06]
Minor Teaching	1.08	0.00	0.14
	[-0.20,2.36]	[-0.05,0.06]	[-0.27,0.55]
System (Ref: Non-system)			
System Member	-0.20	0.00	0.04
	[-0.54,0.15]	[-0.01,0.02]	[-0.07,0.15]
Ownership (Ref: Non Profit)			
Government	1.70*	-0.00	-0.20
	[0.07,3.33]	[-0.07,0.06]	[-0.73,0.32]
For-Profit	0.59	0.04	-0.22
	[-0.54,1.72]	[-0.00,0.09]	[-0.59,0.14]
No. Beds (100's)	0.12	0.01	0.15
	[-0.42,0.67]	[-0.01,0.03]	[-0.03,0.32]
Marketshare (Percent beds)	0.20	-0.02	-0.03
	[-0.51,0.92]	[-0.04,0.01]	[-0.26,0.20]
DSH Percent	-1.38	0.07	-0.83
	[-4.57,1.81]	[-0.06,0.20]	[-1.86,0.20]
Case Mix Index	0.52	-0.02	0.31
	[-1.08,2.11]	[-0.09,0.04]	[-0.20,0.83]
Urban (Ref: Large Urban)			
Other Urban	0.15	0.05	-0.62**
	[-1.32,1.62]	[-0.01,0.11]	[-1.10,-0.15]
Rural	0.35	0.05	-0.19
	[-1.19,1.89]	[-0.01,0.11]	[-0.69,0.30]
Number of SNF's in County	-0.15	-0.01	-0.11**
	[-0.36,0.06]	[-0.01,0.00]	[-0.17,-0.04]
Number of SNF Beds in County (100's)	0.32**	0.01	0.08*
	[0.13,0.51]	[-0.00,0.01]	[0.01,0.14]
Year (Ref: 2009)			

2010	0.49***	-0.02**	0.14**
	[0.20,0.79]	[-0.03,-0.01]	[0.05,0.24]
2011	0.40**	-0.02***	0.21***
	[0.11,0.70]	[-0.04,-0.01]	[0.11,0.31]
2012	0.06	-0.03***	0.28***
	[-0.26,0.38]	[-0.04,-0.01]	[0.17,0.38]
2013	0.39*	-0.03***	0.37***
	[0.06,0.71]	[-0.04,-0.02]	[0.26,0.47]
2014	0.06	-0.04***	0.43***
	[-0.26,0.39]	[-0.05,-0.02]	[0.33,0.54]
2015	-0.15	-0.05***	0.54***
	[-0.51,0.21]	[-0.07,-0.04]	[0.43,0.66]
Constant	2.90	2.90	2.90
	[-1.18,6.98]	[-1.18,6.98]	[-1.18,6.98]
N (Hospital-Years)	14295.00	14295.00	14295.00

Notes: Results based on three separate models, regressing outcomes in each column on hospital characteristics, hospital fixed effects, and year fixed effects; *p<0.05, **p<0.01, ***p<0.001

Table 6. Marginal Effects of BPCI Participation on SNF Quality

	(1)	(2)	(3)	(4)
BPCI Participation	Survey Rating	Outcome Rating	Staffing Rating	RN Staffing Rating
Average Marginal Effect	0.04	0.20***	-0.01	0.04
95% Confidence Interval	[-0.03,0.11]	[0.14,0.26]	[-0.07,0.04]	[-0.09,0.02]
p-value	0.307	<0.001	0.61	0.20

Notes: Results shown based on 4 separate Poisson regression models (1 for each SNF quality measure) regressing a given patient's SNF quality on hospital fixed effects, year fixed effects, and hospital characteristics weighted by the inverse of the number of discharges per hospital; *p<0.05, **p<0.01, ***p<0.001

Appendices

Appendix A: Supplemental Material for Chapter 1

Table 7. Hospital Statistics In and Out of Sample for Chapter 1

Characteristics	All Hospitals (n=3,969)	Hospitals In Sample (n=2,836)	Hospitals Dropped due to Missing Data (n=1,133)[1]
APM Participation (No. %)***			
Ever in APM	1774 (45%)	1451 (51%)	323 (29%)
Ever in ACO	1340 (34%)	1110 (39%)	230 (20%)
Ever in Medical Home	953 (24%)	819 (29%)	134 (12%)
Ever in BPCI	106 (3%)	98 (3%)	8 (1%)
Never in APM	2195 (55%)	1385 (49%)	810 (71%)
Total[1]	3969 (100%)	2836 (100%)	1133 (100%)
Has Primary Care Department[2] (No. %)*			
No	923 (36%)	911 (36%)	12 (63%)
Yes	1614 (64%)	1607 (64%)	7 (37%)
Total	2537 (100%)	2518 (100%)	19 (100%)
Urban/Rural Classification (No. %)			
Large Urban	1285 (41%)	1171 (41%)	114 (40%)
Other Urban	1041 (33%)	953 (34%)	88 (31%)
Rural	793 (25%)	712 (25%)	81 (29%)
Total	3119 (100%)	2836 (100%)	283 (100%)
Teaching Hospital (No. %)***			
Non-teaching	2369 (60%)	1439 (51%)	930 (84%)
Major (COTH)	235 (6%)	232 (8%)	3 (0%)
Minor (Med. School Affiliation)	1333 (34%)	1165 (41%)	168 (15%)
Total	3937 (100%)	2836 (100%)	1101 (100%)
System Membership (No. %)***			
Not in a system	1309 (33%)	795 (28%)	514 (47%)
In a system	2628 (67%)	2041 (72%)	587 (53%)
Total	3937 (100%)	2836 (100%)	1101 (100%)
Network Membership (No. %)			
Not in a network	2072 (57%)	1616 (57%)	456 (57%)
In a network	1564 (43%)	1220 (43%)	344 (43%)
Total	3636 (100%)	2836 (100%)	800 (100%)
Ownership (No. %)***			
Government	764 (19%)	424 (15%)	340 (31%)
Non-Profit	2448 (62%)	1850 (65%)	598 (54%)
For-Profit	725 (18%)	562 (20%)	163 (15%)
Total	3937 (100%)	2836 (100%)	1101 (100%)

Characteristics	**All Hospitals (n=3,969)**	**Hospitals In (n=2,836)**	**Hospitals Dropped (n=1,133)**[1]
Number of Beds (Mean (SD))***	196 (187)	251 (210)	144 (144)
DSH Percentage (Mean (SD))	0.29 (0.17)	0.28 (0.17)	0.29 (0.18)
Case Mix Index (Mean (SD))	1.55 (0.34)	1.62 (0.29)	1.48 (0.37)
Hospital Marketshare (Mean (SD))***	1.43 (1.99)	1.73 (2.23)	1.15 (1.69)

Notes: [1]Number of observations varies due to missing data [2]Either owned or affiliated through a system or joint venture, not included in models. Hospital characteristics based on more recent available year of data per hospital. Difference between hospitals in sample and not in sample are statistically significant at ***p<0.001, **p<0.01, *p<0.05; Marketshare calculated as the percentage of beds in hospital system in hospital referral region. Statistics assume that hospitals missing data on Medical Home participation did not participate in a Medical Home.

Table 8. Sensitivity Analysis for Chapter 1: Number of APM Types

Marginal Effects	(1) Patient Engagement
Each Additional APM	0.126
	[-0.054,0.306]
Controls	
No. Beds	-0.004***
	[-0.006,-0.003]
Urban (Ref: Large Urban)	
Other Urban	1.016**
	[0.329,1.702]
Rural	0.860*
	[0.121,1.599]
DSH Percent	-8.701***
	[-10.430,-6.972]
Case Mix Index	4.745***
	[3.853,5.637]
Teaching (Ref: Non-Teaching)	
Major Teaching	0.259
	[-0.021,0.538]
Minor Teaching	0.747*
	[0.165,1.329]
System (Ref: Non-system)	
System Member	-0.234
	[-0.504,0.036]
Network (Ref: Non-network)	
Network Member	-0.033
	[-0.378,0.312]
Ownership (Ref: Government)	
Non-profit	-0.322
	[-0.998,0.354]
For-profit	-1.885***
	[-2.707,-1.062]
Marketshare (System HHI in HRR)	-0.133*
	[-0.247,-0.020]
Year (Ref: 2013)	
2014	0.898***
	[0.735,1.060]
2015	0.724***
	[0.505,0.943]
2016	0.529***
	[0.319,0.740]
Constant	46.930***
	[45.312,48.548]
N (Hospital-Years)	9648.000

Note: 95% confidence intervals in brackets. ***p<0.001, **p<0.01, *p<0.05

Table 9. Sensitivity Analysis for Chapter 1: Non-Missing Variables

Marginal Effects	(1) Patient Engagement and Readmission Rate	(2) APM and Patient Engagement
Patient Engagement	-0.013***	
	[-0.018,-0.008]	
Full Year APM Participation		0.304
		[-0.010,0.618]
Controls		
No. Beds	0.001***	-0.004***
	[0.001,0.001]	[-0.005,-0.002]
Urban (Ref: Large Urban)		
Other Urban	-0.199***	1.164**
	[-0.303,-0.094]	[0.447,1.880]
Rural	-0.184**	1.047**
	[-0.303,-0.065]	[0.286,1.808]
DSH Percent	0.853***	-10.175***
	[0.556,1.150]	[-11.916,-8.434]
Case Mix Index	-0.574***	4.913***
	[-0.711,-0.437]	[3.961,5.864]
Teaching (Ref: Non-Teaching)		
Major Teaching	0.459***	0.449
	[0.331,0.588]	[-0.248,1.147]
Minor Teaching	0.045	-0.246
	[-0.013,0.104]	[-0.540,0.047]
System (Ref: Non-system)		
System Member	-0.034	-0.260
	[-0.078,0.010]	[-0.534,0.015]
Network (Ref: Non-network)		
Network Member	-0.040	-0.044
	[-0.094,0.015]	[-0.402,0.315]
Ownership (Ref: Government)		
Non-profit	0.023	-0.860*
	[-0.076,0.123]	[-1.555,-0.166]
For-profit	0.278***	-2.651***
	[0.149,0.407]	[-3.495,-1.806]
Marketshare (System HHI in HRR)	-4.306***	-15.684*
	[-6.811,-1.800]	[-28.000,-3.368]
Year (Ref: 2013)		
2014	0.360***	0.866***
	[0.326,0.395]	[0.698,1.035]
2015	0.088***	0.719***
	[0.052,0.125]	[0.504,0.934]
Constant	16.448***	47.620***
	[16.105,16.791]	[45.894,49.346]
N (Hospital-Years)	6836.000	6838.000

Note: 95% confidence intervals in brackets. ***p<0.001, **p<0.01, *p<0.05

Appendix B: Supplemental Material for Chapter 2

Table 10. Descriptive Statistics for Hospitals In and Out of Sample for Chapter 2

	Hospitals without Data on Volume	Hospitals with Data on Volume	
	No. (%)	No. (%)	p-value
APM Participation			<0.001
Never Participated	1004 (70%)	32 (4%)	
Ever in 1 APM Type	339 (24%)	359 (45%)	
Ever in 2 APM Types	90 (6%)	311 (39%)	
Ever in 3 APM Types	2 (0.1%)	96 (12%)	
Ever Participated	431 (30%)	766 (96%)	
Total (Never + Ever)	1435 (100%)	798 (100%)	
Size			<0.001
< 100 Beds	653 (46%)	183 (23%)	
100-399 beds	656 (46%)	457 (57%)	
400+ beds	126 (9%)	158 (20%)	
Total	1435 (100%)	798 (100%)	
Urbanicity			<0.001
Large Urban	482 (34%)	433 (54%)	
Other Urban	485 (34%)	249 (31%)	
Rural	468 (33%)	116 (15%)	
Total	1435 (100%)	798 (100%)	
Teaching			<0.001
Non-Teaching	820 (57%)	300 (38%)	
Major	73 (5%)	111 (14%)	
Minor	542 (38%)	387 (49%)	
Total	1435 (100%)	798 (100%)	
System Membership			<0.001
Not in System	542 (38%)	136 (17%)	
In System	893 (62%)	662 (83%)	
Total	1435 (100%)	798 (100%)	
Network Membership			<0.001
Not in Network	893 (62%)	330 (41%)	
In Network	542 (38%)	468 (59 %)	
Total	1435 (100%)	798 (100%)	
Ownership			<0.001
Government	235 (16%)	80 (10 %)	
Non-Profit	828 (58%)	659 (83%)	
For-Profit	372 (26%)	59 (7%)	
Total	1435 (100%)	798 (100%)	

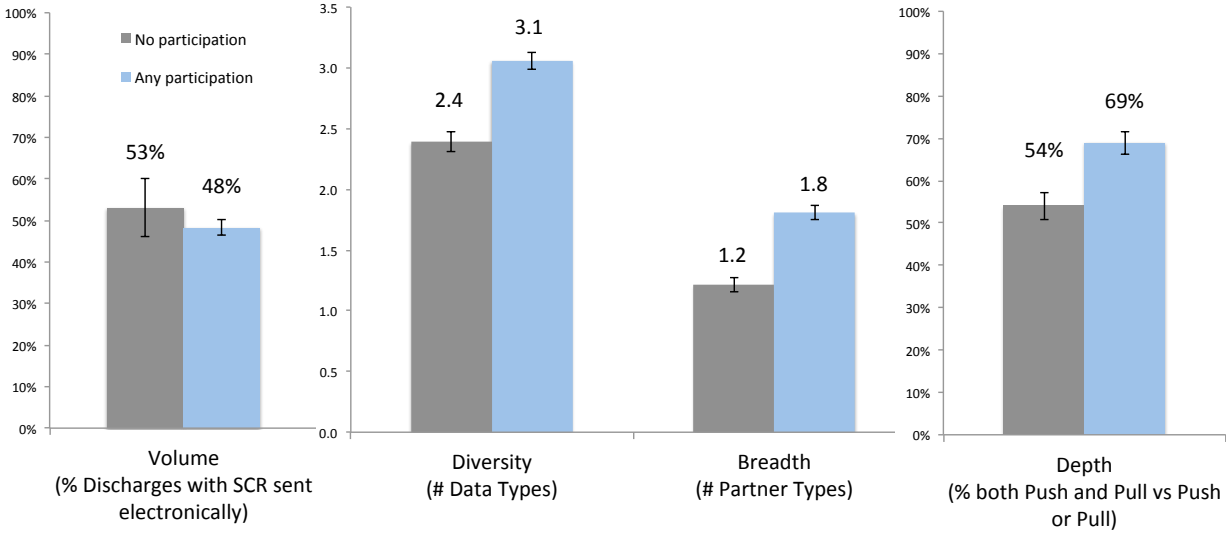
	Hospitals without Data on Volume	Hospitals with Data on Volume	
	Mean (SD)	Mean (SD)	p-value
DSH percent	0.3 (0.2)	0.3 (0.2)	0.007
Case Mix Index	1.5 (0.3)	1.6 (0.3)	<0.001
Marketshare	1.6 (2.3)	2.0 (2.6)	<0.001
No. of SNF Facilities (County)	17 (26)	30 (40)	<0.001
No. of Hospitals (County)	8 (13)	11 (14)	<0.001
No. of PCPs (County)	382 (660)	722 (1011)	<0.001

	Hospitals without Data on Volume	Hospitals with Data on Volume	
	No. (%)	No. (%)	p-value
APM Participation			<0.001
Never Participated	1004 (70%)	32 (4%)	
Ever in 1 APM Type	339 (24%)	359 (45%)	
Ever in 2 APM Types	90 (6%)	311 (39%)	
Ever in 3 APM Types	2 (0.1%)	96 (12%)	
Ever Participated	431 (30%)	766 (96%)	
Total (Never + Ever)	1435 (100%)	798 (100%)	
Size			<0.001
< 100 Beds	653 (46%)	183 (23%)	
100-399 beds	656 (46%)	457 (57%)	
400+ beds	126 (9%)	158 (20%)	
Total	1435 (100%)	798 (100%)	
Urbanicity			<0.001
Large Urban	482 (34%)	433 (54%)	
Other Urban	485 (34%)	249 (31%)	
Rural	468 (33%)	116 (15%)	
Total	1435 (100%)	798 (100%)	
Teaching			<0.001
Non-Teaching	820 (57%)	300 (38%)	
Major	73 (5%)	111 (14%)	
Minor	542 (38%)	387 (49%)	
Total	1435 (100%)	798 (100%)	
System Membership			<0.001
Not in System	542 (38%)	136 (17%)	
In System	893 (62%)	662 (83%)	
Total	1435 (100%)	798 (100%)	
Network Membership			<0.001
Not in Network	893 (62%)	330 (41%)	
In Network	542 (38%)	468 (59 %)	
Total	1435 (100%)	798 (100%)	
Ownership			<0.001
Government	235 (16%)	80 (10 %)	
Non-Profit	828 (58%)	659 (83%)	
For-Profit	372 (26%)	59 (7%)	
Total	1435 (100%)	798 (100%)	
	Mean (SD)	Mean (SD)	p-value
DSH percent	0.3 (0.2)	0.3 (0.2)	0.007
Case Mix Index	1.5 (0.3)	1.6 (0.3)	<0.001
Marketshare	1.6 (2.3)	2.0 (2.6)	<0.001
No. of SNF Facilities (County)	17 (26)	30 (40)	<0.001
No. of Hospitals (County)	8 (13)	11 (14)	<0.001
No. of PCPs (County)	382 (660)	722 (1011)	<0.001

	Hospitals without Data on Diversity and Breadth	Hospitals with Data on Diversity and Breadth	
	No. (%)	No. (%)	p-value
APM Participation			<0.001
Never Participated	286 (57 %)	750 (43%)	
Ever in 1 APM Type	135 (27%)	563 (33%)	
Ever in 2 APM Types	59 (12%)	342 (20%)	
Ever in 3 APM Types	23 (5%)	75 (4%)	
Ever Participated	217 (4%)	980 (57%)	
Total (Never + Ever)	503 (100%)	1730 (100%)	
Size			<0.001
< 100 Beds	260 (52%)	576 (33%)	
100-399 beds	210 (42 %)	903 (52%)	
400+ beds	33 (7%)	251 (15%)	
Total	503 (100%)	1730 (100%)	
Urbanicity			0.001
Large Urban	183 (36%)	732 (42%)	
Other Urban	159 (32%)	575 (33%)	
Rural	161 (32%)	423 (24%)	
Total	503 (100%)	1730 (100%)	
Teaching			<0.001
Non-Teaching	306 (61%)	814 (47%)	
Major	13 (3%)	171 (10%)	
Minor	184 (37%)	745 (43%)	
Total	503 (100%)	1730 (100%)	
System Membership			0.26
Not in System	158 (31.41%)	520 (30%)	
In System	345 (68.59%)	1210 (70%)	
Total	503 (100%)	1730 (100%)	
Network Membership			<0.001
Not in Network	316 (63%)	907 (52%)	
In Network	187 (37%)	823 (48%)	
Total	503 (100%)	1730 (100%)	
Ownership			<0.001
Government	72 (14%)	243 (14%)	
Non-Profit	269 (54%)	1218 (70%)	
For-Profit	162 (32%)	269 (16%)	
Total	503 (100%)	1730 (100%)	
	Mean (SD)	Mean (SD)	p-value
DSH percent	0.3 (0.2)	0.3 (0.2)	0.018
Case Mix Index	1.5 (0.4)	1.5 (0.3)	<0.001
Marketshare	1.3 (1.9)	1.9 (2.5)	<0.001
No. of SNF Facilities (County)	17 (26)	23 (34)	<0.001
No. of Hospitals (County)	9 (14)	10 (14)	0.161
No. of PCPs (County)	406 (678)	532 (854)	0.002

	Hospitals without Data on Depth	Hospitals with Data on Depth	
	No. (%)	No. (%)	p-value
APM Participation			<0.001
Never Participated	465 (58%)	571 (40%)	
Ever in 1 APM Type	213 (26%)	485 (34%)	
Ever in 2 APM Types	99 (12%)	302 (21%)	
Ever in 3 APM Types	29 (4%)	69 (5%)	
Ever Participated	341 (42%)	856 (60%)	
Total (Never + Ever)	806 (100%)	1427 (100%)	
Size			<0.001
< 100 Beds	402 (50%)	434 (30%)	
100-399 beds	351 (44%)	762 (53%)	
400+ beds	53 (7%)	231 (16%)	
Total	806 (100%)	1427 (100%)	
Urbanicity			0.001
Large Urban	302 (37%)	613 (43%)	
Other Urban	248 (31%)	486 (34%)	
Rural	256 (32%)	328 (23%)	
Total	806 (100%)	1427 (100%)	
Teaching			<0.001
Non-Teaching	484 (60%)	636 (45%)	
Major	26 (3%)	158 (11%)	
Minor	296 (37%)	633 (44%)	
Total	806 (100%)	1427 (100%)	
System Membership			0.43
Not in System	253 (31%)	425 (30%)	
In System	553 (69%)	1002 (70%)	
Total	806 (100%)	1427 (100%)	
Network Membership			<0.001
Not in Network	496 (62%)	727 (51%)	
In Network	310 (38%)	700 (49%)	
Total	806 (100%)	1427 (100%)	
Ownership			<0.001
Government	124 (15%)	191 (13%)	
Non-Profit	447 (56%)	1040 (73%)	
For-Profit	235 (29%)	196 (14%)	
Total	806 (100%)	1427 (100%)	
	Mean (SD)	Mean (SD)	p-value
DSH percent	0.3 (0.2)	0.3 (0.2)	0.89
Case Mix Index	1.5 (0.4)	1.6 (0.3)	<0.001
Marketshare	1.2 (1.9)	2.0 (2.7)	<0.001
No. of SNF Facilities (County)	18 (27)	25 (35)	<0.001
No. of Hospitals (County)	8 (13)	10 (14)	0.11
No. of PCPs (County)	413 (692)	413 (692)	<0.001

Figure 6. Unadjusted Performance on Four Dimensions of HIE Engagement by APM Participation for Chapter 2



Notes: Average shown in bars, 95% confidence interval shown in lines. Measures of HIE volume based on 801 hospitals, data on HIE diversity, breadth based on 2,085 hospitals, data on HIE depth based on 1427 hospitals pooled across 2014 and 2015

Table 11. Full Regression Results for Chapter 2: Adjusted Association between APM Participation and Dimensions of HIE Engagement

	(1) Volume	(2) Diversity	(3) Breadth	(4) Depth (OR)
Full Year APM participation	-0.11***	0.31***	0.29***	1.68**
	(0.03)	(0.07)	(0.05)	(0.307)
Size (Ref: <100 beds)				
100-399 beds	-0.02	0.16	0.11	1.60*
	(0.02)	(0.09)	(0.07)	(0.376)
400+ beds	-0.06	0.20	0.10	2.28*
	(0.04)	(0.13)	(0.11)	(0.889)
Urban (Ref: Large Urban)				
Other Urban	0.00	0.04	0.03	0.48**
	(0.02)	(0.08)	(0.07)	(0.110)
Rural	-0.01	-0.07	0.07	0.41**
	(0.03)	(0.10)	(0.08)	(0.112)
Teaching (Ref: Non-Teaching)				
Major	-0.05	0.21	0.13	1.99
	(0.04)	(0.13)	(0.11)	(0.826)
Minor	-0.02	0.12	0.02	1.19
	(0.02)	(0.07)	(0.06)	(0.238)
System (Ref: Not in System)				
In System	0.05	0.20*	0.15*	2.27***
	(0.03)	(0.08)	(0.06)	(0.488)
Network (Ref: Not in Network)				
In Network	-0.00	-0.02	0.12*	0.93
	(0.02)	(0.06)	(0.05)	(0.159)
Ownership (Ref: Government)				
Non-Profit	-0.02	0.23*	-0.05	2.26**
	(0.03)	(0.10)	(0.08)	(0.561)
For-Profit	-0.16***	-0.38**	-0.70***	2.64**
	(0.04)	(0.13)	(0.10)	(0.910)
DSH percent	0.06	-0.56*	-0.19	0.21*
	(0.07)	(0.22)	(0.18)	(0.133)
Case Mix Index	0.02	0.40**	0.28**	1.05
	(0.04)	(0.14)	(0.10)	(0.398)
CAH Status (Ref: Not CAH)				
CAH	-0.33***	-0.53	-0.13	3.34
	(0.02)	(0.64)	(0.43)	(5.019)
Marketshare	0.01	0.02	0.02	0.99
	(0.00)	(0.01)	(0.01)	(0.037)
No. of SNF Facilities (County)	0	0.01***	0.01**	1.01
	(0.00)	(0.00)	(0.00)	(0.008)
No. of Hospitals (County)	0.00	-0.01*	-0.01**	1.00
	(0.00)	(0.01)	(0.00)	(0.015)
No. of PCPs (County)	-0.00	-0.00*	-0.00	1.00
	(0.00)	(0.00)	(0.00)	(0.000)
Year (Ref: 2014)				
2015	0.26***	0.34***	0.30***	1.97***
	(0.01)	(0.05)	(0.04)	(0.285)
N (Hospital-Year Obs)	1199.00	2906.00	2906.00	2192.00

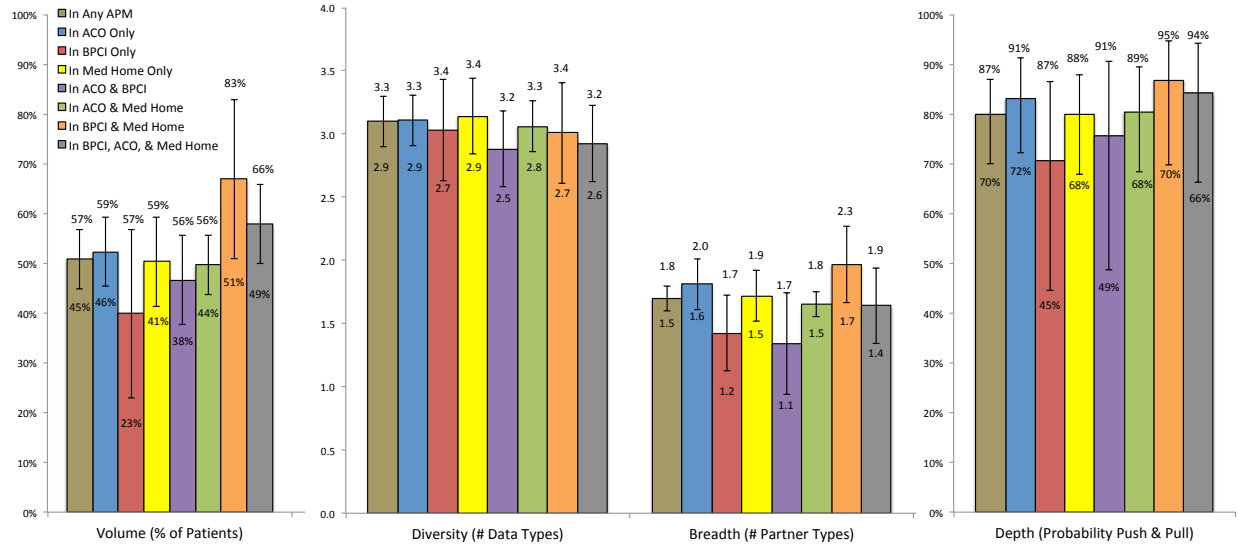
Note: Hospital-clustered SE in parentheses, modles include hospital mixed effects

Table 12. Sensitivity Analysis for Chapter 2: Participation in Multiple APM Types

	(1) Volume	(2) Diversity	(3) Breadth	(4) Depth (OR)
Full Year Participation (Ref: No Participation)				
In 1 APM Type	-0.11**	0.35***	0.32***	1.65**
	(0.034)	(0.070)	(0.057)	(0.323)
In 2 APM Types	-0.12***	0.24**	0.23**	1.71*
	(0.035)	(0.088)	(0.072)	(0.420)
In 3 APM Types	-0.04	0.12	0.21	2.05
	(0.044)	(0.166)	(0.135)	(1.054)
Size (Ref: <100 beds)				
100-399 beds	-0.02	0.16*	0.11	1.60*
	(0.026)	(0.082)	(0.066)	(0.376)
400+ beds	-0.06	0.21	0.10	2.26*
	(0.039)	(0.135)	(0.110)	(0.882)
Urban (Ref: Large Urban)				
Other Urban	0.00	0.03	0.03	0.48**
	(0.024)	(0.082)	(0.066)	(0.110)
Rural	-0.01	-0.07	0.07	0.41**
	(0.032)	(0.096)	(0.078)	(0.112)
Teaching (Ref: Non-Teaching)				
Major	-0.05	0.23	0.14	1.98
	(0.037)	(0.138)	(0.112)	(0.822)
Minor	-0.02	0.13	0.02	1.19
	(0.022)	(0.072)	(0.058)	(0.237)
System (Ref: Not in System)				
In System	0.04	0.20**	0.15*	2.26***
	(0.027)	(0.075)	(0.061)	(0.485)
Network (Ref: Not in Network)				
In Network	-0.00	-0.01	0.12*	0.93
	(0.018)	(0.060)	(0.049)	(0.158)
Ownership (Ref: Government)				
Non-Profit	-0.02	0.23*	-0.05	2.25**
	(0.032)	(0.091)	(0.074)	(0.560)
For-Profit	-0.16***	-0.38**	-0.70***	2.65**
	(0.045)	(0.118)	(0.096)	(0.912)
DSH percent	0.07	-0.56**	-0.19	0.21*
	(0.067)	(0.207)	(0.168)	(0.134)
Case Mix Index	0.02	0.41**	0.28**	1.04
	(0.042)	(0.124)	(0.101)	(0.395)
CAH Status (Ref: Not CAH)				
CAH	-0.33	-0.54	-0.14	3.36
	(0.274)	(0.509)	(0.413)	(5.046)
Marketshare	0.01	0.02	0.02	0.99
	(0.004)	(0.014)	(0.012)	(0.037)
No. of SNF Facilities (County)	-0.00	0.01***	0.01*	1.01
	(0.001)	(0.003)	(0.002)	(0.008)
No. of Hospitals (County)	0.00	-0.01*	-0.01**	1.00
	(0.002)	(0.005)	(0.004)	(0.015)
No. of PCPs (County)	-0.00	-0.0002*	-0.00	1.00
	(0.000)	(0.000)	(0.000)	(0.000)

Note: Hospital-clustered SE in parentheses, hospital mixed and year fixed effects not shown

Figure 7. Sensitivity Analysis for Chapter 2: Comparing Any APM Participation to Participation by APM Type, Predicted Performance on Four Dimensions of Hospital HIE Engagement



Notes: Predicted values for medium sized, urban, non teaching, non system member, non network member, non-profit, non critical access hospitals with all other continuous variables at the sample mean; predictions based on models with a 3-way interaction term interacting any year participation in each of 3 APM types.

Table 13. Sensitivity Analysis for Chapter 2: Negative Binomial Model

	(1) Diversity	(2) Breadth
Full Year APM participation	0.12***	0.19***
	(0.026)	(0.035)
Size (Ref: <100 beds)		
100-399 beds	0.05	0.09*
	(0.034)	(0.045)
400+ beds	0.06	0.08
	(0.048)	(0.070)
Urban (Ref: Large Urban)		
Other Urban	0.02	0.01
	(0.029)	(0.042)
Rural	-0.02	0.05
	(0.038)	(0.051)
Teaching (Ref: Non-Teaching)		
Major	0.07	0.06
	(0.045)	(0.067)
Minor	0.05	0.02
	(0.027)	(0.037)
System (Ref: Not in System)		
In System	0.09**	0.12*
	(0.031)	(0.047)
Network (Ref: Not in Network)		
In Network	-0.01	0.06*
	(0.022)	(0.032)
Ownership (Ref: Government)		
Non-Profit	0.08*	-0.04
	(0.040)	(0.047)
For-Profit	-0.17**	-0.65***
	(0.057)	(0.072)
DSH percent	-0.21*	-0.12
	(0.093)	(0.111)
Case Mix Index	0.16**	0.18**
	(0.055)	(0.070)
CAH Status (Ref: Not CAH)		
CAH	-0.24	-0.13
	(0.301)	(0.335)
Marketshare	0.01	0.01
	(0.004)	(0.007)
No. of SNF Facilities (County)	0.00***	0.00**
	(0.001)	(0.001)
No. of Hospitals (County)	-0.01*	-0.01**
	(0.002)	(0.003)
No. of PCPs (County)	-0.00*	-0.00
	(0.000)	(0.000)
N (Hospital-Year Obs)	2906.00	2906.00

Note: Hospital-clustered SE in parentheses, all models contain year fixed effects (not shown) n=2906

Table 14. Sensitivity Analysis for Chapter 2: Heckman Selection Model

	(1) Volume		(2) Attestation (Selection)	
Full Year APM participation	-0.10**	(0.032)	0.30***	(0.090)
Size (Ref: <100 beds)				
100-399 beds	-0.00	(0.022)	0.05	(0.081)
400+ beds	-0.04	(0.034)	0.11	(0.119)
Urban (Ref: Large Urban)				
Other Urban	0.02	(0.021)	0.03	(0.068)
Rural	0.00	(0.027)	0.07	(0.091)
Teaching (Ref: Non-Teaching)				
Major	-0.11***	(0.033)	-0.14	(0.112)
Minor	-0.04	(0.019)	0.02	(0.062)
System (Ref: Not in System)				
In System	0.06*	(0.027)	-0.05	(0.139)
Network (Ref: Not in Network)				
In Network	-0.02	(0.015)	-0.03	(0.054)
Ownership (Ref: Government)				
Non-Profit	-0.06	(0.031)	-0.08	(0.102)
For-Profit	-0.21***	(0.035)	-0.03	(0.129)
DSH percent	0.12	(0.063)	0.14	(0.197)
Case Mix Index	0.05	(0.036)	-0.08	(0.130)
CAH Status (Ref: Not CAH)				
CAH	-0.06	(0.053)	-1.25	(0.725)
Marketshare	0.00	(0.004)	-0.01	(0.013)
No. of SNF Facilities (County)	-0.00*	(0.001)	-0.00	(0.002)
No. of Hospitals (County)	0.00**	(0.001)	-0.01	(0.004)
No. of PCPs (County)	-0.00	(0.000)	0.00*	(0.000)
Year (Ref: 2014)				
2015	0.09***	(0.012)	0.49***	(0.083)
Latest S1 Attestation Year (Ref: Never)				
2012			10.69***	(0.302)
2013			3.65***	(0.177)
2014			2.76***	(0.172)
2015			-4.58***	(0.174)
2016			-4.59***	(0.177)
athrho	-0.42***	(0.061)		
N	4310.00			

Note: Hospital-clustered SE in Parentheses, all models contain year fixed effects. For more details on this methodology, see Lin, Everson, and Adler-Milstein, 2018.(13)

Appendix C: Supplemental Material for Chapter 3

Appendix Exhibit C 1. SNF Star Rating Measures

Measure details from (85) and (90); see referenced material for details methodology

- ***Health Inspections - Measures based on outcomes from State health inspection surveys:*** Facility ratings for the health inspection domain are based on the number, scope, and severity of deficiencies identified during the three most recent annual health inspection surveys, as well as substantiated findings from the most recent 36 months of complaint investigations. All deficiency findings are weighted by scope and severity. This measure also takes into account the number of revisits required to ensure that deficiencies identified during the health inspection survey have been corrected.

- ***Staffing - Measures based on nursing home staffing levels:*** Facility ratings on the staffing domain are based on two measures: 1) Registered Nurse (RN) hours per resident day; and 2) total nursing hours (the sum of RN, Licensed Practical Nurse (LPN), and Certified Nurse Aides (CNA)) per resident day. Other clinical personnel such as therapists and social workers are not included in these staffing measures, nor are other non-clinical staff, such as clerical, administrative, or housekeeping staff.

- ***Quality Measures - Measures based on MDS quality measures (QMs):*** Facility ratings for the QMs are based on performance on 10 of the 19 QMs that were posted on the *Nursing Home Compare* web site. These include seven long-stay measures and three short-stay measures. The QMs that are included in the rating were selected from among the publicly reported QMs based on several criteria, including clinical importance, the extent to which the measure is under facility control, and statistical performance, including reliability, validity and variability:

  Quality Measures for long-stay residents:
  - Percent of residents whose need for help with daily activities has increased
  - Percent of residents whose ability to move in and around their room got worse
  - Percent of high risk residents with pressure sores
  - Percent of residents who had a catheter inserted and left in their bladder
  - Percent of residents who were physically restrained
  - Percent of residents with a urinary tract infection
  - Percent of residents who have moderate to severe pain

  Quality Measures for short-stay residents:
  - Percent of residents with pressure ulcers (sores)
  - Percent of residents who had moderate to severe pain
  - Percent of residents with delirium

Appendix Exhibit C 2. Hospital and SNF Matching Data for Chapter 3

Original network data (159,775 discharges):
- 2,765 Hospitals
- 12,773 SNFs

Observations Matched to Hospital Characteristics Data:
- 2,727 Hospitals (38 unsuccessfully matched)

Final Hospital-year level Dataset with Hospital Characteristics:
- 14,295 hospital-year observations on
- 2,354 hospitals (373 hospitals missing data on one or more control measures)

Observations Matched to SNF Quality and Characteristics Data:
- 11,767 SNFs
- 10,903 SNFs (864 SNFs dropped because partnering hospitals were missing data)

Final Discharge-level Dataset with Hospital and SNF Quality Data:
- 139,452 Discharges
- 10,383 SNFs (520 SNFs missing data on one or more SNF measures)
- 2,346 Hospitals (8 hospital dropped because their SNF partners were missing data)
- 127,898 Beneficiaries

Table 15. Hospitals and SNFs In and Out of Sample for Chapter 3

Hospital Characteristics	All Hospitals (n=2,765)	Hospitals In Sample (n=2,354)	Hospitals Dropped due to Missing Data[2] (n=419)[1]
Hospital offers SNF Services (No. %)			
In Hospital*	422 (16%)	386 (16%)	36 (11%)
In System	412 (15%)	362 (15%)	50 (16%)
Through Joint Venture	78 (3%)	68 (3%)	10 (3%)
Urban/Rural Classification (No. %)***			
Large Urban	1149 (42%)	964 (41%)	185 (50%)
Other Urban	960 (35%)	816 (35%)	144 (39%)
Rural	614 (23%)	574 (24%)	40 (11%)
Total[1]	2723 (100%)	2354 (100%)	369 (100%)
Teaching Hospital (No. %)			
Non-teaching	1325 (49%)	1169 (50%)	156 (48%)
Major (COTH)	230 (9%)	200 (9%)	30 (9%)
Minor (Med. School Affiliation)	1124 (42%)	985 (42%)	139 (43%)
Total[1]	2679 (100%)	2354 (100%)	325 (100%)
System Membership (No. %)			
Not in a system	635 (24%)	562 (24%)	73 (22%)
In a system	2044 (76%)	1792 (76%)	252 (78%)
Total[1]	2679 (100%)	2354 (100%)	325 (100%)
Ownership (No. %)			
Government	309 (12%)	268 (11%)	41 (13%)
Non-Profit	1763 (66%)	1559 (66%)	204 (63%)
For-Profit	607 (23%)	527 (22%)	80 (25%)
Total[1]	2679 (100%)	2354 (100%)	325 (100%)
Number of Beds in 100s (Mean (SD))***	2 (8)	2 (2)	4 (21)
Hospital Marketshare (Mean (SD))	1.59 (2.08)	1.6 (2.11)	1.55 (1.79)
DSH Percentage (Mean (SD))	0.27 (0.15)	0.27 (0.15)	0.27 (0.16)
Case Mix Index (Mean (SD))***	1.56 (0.3)	1.54 (0.29)	1.67 (0.33)
No. SNF Facilities in County (Mean (SD))	22.54 (31.97)	22.51 (31.97)	29.67 (32.43)
No. SNF Beds in County in 100s (Mean (SD))***	30.39 (31.97)	30.04 (50.56)	121.91 (204.48)

SNF Characteristics	All SNFs (n=12,773)	SNFs in Sample (n=10,383)	SNFs dropped due to missing data (n=2,390)
Ever in ACO (No. %)***	154 (1%)	95 (1%)	59 (2%)
SNF in Chain (No. %)*			
Not in a chain	4323 (39%)	4041 (39%)	282 (44%)
In a chain	6702 (61%)	6342 (61%)	360 (56%)
Total	11025 (100%)	10383 (100%)	642 (100%)
Ownership (No. %)**			
Government	601 (5%)	510 (5%)	91 (7%)
Non-Profit	3108 (26%)	2717 (26%)	391 (29%)
For-Profit	8030 (68%)	7156 (69%)	874 (64%)
Total	11739 (100%)	10383 (100%)	1356 (100%)
Number of Beds (Mean (SD))***	110 (62)	112 (62)	96 (60)
Occupancy Rate (Mean (SD))***	0.82 (0.2)	0.83 (0.19)	0.75 (0.26)
Percent Residents Medicare (Mean (SD))***	0.19 (0.21)	0.19 (0.2)	0.27 (0.33)
Percent Residents Medicaid (Mean (SD))***	0.58 (0.27)	0.59 (0.27)	0.48 (0.31)

Notes: Difference between in and out of sample significant at *p<0.05, **p<0.01, ***p<0.001; [1]N varies based on missingness; [2] Of hospitals represented in the original network data; statistics based on most recent year of data per hospital /SNF

Table 16. Sensitivity Analysis for Chapter 3: Subset of Observations with All Data

Marginal Effects	(1) No. Discharges	(2) Concentration	(3) No. SNF
BPCI Participation for Joint Replacement	-1.88***	-0.01	-0.15
	[-2.76,-1.00]	[-0.04,0.03]	[-0.43,0.13]

Notes: Marginal effect significant at *p<0.05, **p<0.01, ***p<0.001; results based on three separate models, regressing outcomes in each column on hospital characteristics, hospital fixed effects, and year fixed effects (not shown).

BPCI Participation	(1) Survey Rating	(2) Outcome Rating	(3) Staffing Rating	(4) RN Staffing Rating
Average Marginal Effect	0.001	0.20***	-0.004	-0.03
95% Confidence Interval	[-0.07,0.07]	[0.14,0.26]	[-0.06,0.05]	[-0.08,0.03]

Notes: Average marginal effect significant at *p<0.05, **p<0.01, ***p<0.001; results shown based on 4 separate Poisson regression models (1 for each SNF quality measure) regressing a given patient's SNF quality on hospital fixed effects, year fixed effects, and hospital characteristics weighted by the inverse of the number of discharges per hospital

Table 17. Sensitivity Analysis for Chapter 3: Fractional Response Regression for SNF Referral Concentration

	(1)
Marginal Effects	Concentration
BPCI Participation for Joint Replacement	-0.07
	[-0.25,0.11]
Controls	
No. of SNF Discharges	-0.03***
	[-0.04,-0.02]
ACO Participation	0.00
	[-0.08,0.08]
Hospital Offers Skilled Nursing care	
Through Hospital	0.46***
	[0.38,0.55]
Through System	-0.02
	[-0.11,0.07]
Through Joint Venture	-0.11
	[-0.34,0.12]
Teaching (Ref: Non-Teaching)	
Major Teaching	0.04
	[-0.03,0.11]
Minor Teaching	0.20**
	[0.06,0.34]
System (Ref: Non-system)	
System Member	-0.11**
	[-0.18,-0.04]
Ownership (Ref: Non Profit)	
Government	0.00
	[-0.11,0.11]
For-Profit	0.14**
	[0.05,0.23]
No. Beds (100's)	-0.15***
	[-0.19,-0.12]
Marketshare (Percent beds)	-0.07***
	[-0.09,-0.04]
DSH Percent	1.26***
	[0.94,1.58]
Case Mix Index	-0.75***
	[-0.93,-0.57]
Urban (Ref: Large Urban)	
Other Urban	0.03
	[-0.08,0.15]
Rural	0.20**
	[0.08,0.33]
Number of SNF's in County	-0.01
	[-0.02,0.00]
Number of SNF Beds in County (100's)	0.01
	[-0.00,0.01]

Year (Ref: 2009)	
2010	-0.08**
	[-0.13,-0.03]
2011	-0.15***
	[-0.21,-0.10]
2012	-0.17***
	[-0.23,-0.11]
2013	-0.18***
	[-0.25,-0.11]
2014	-0.17***
	[-0.24,-0.11]
2015	-0.21***
	[-0.29,-0.14]
N (Hospital-Years)	14295.00

Notes: Results based on a single model, regressing hospital-SNF HHI in each column on hospital characteristics, hospital fixed effects, and year fixed effects.

Table 18. Sensitivity Analysis 3 for Chapter 3: After Dropping Hospital-SNF Pairs Not in the Same HRR

Marginal Effects	(1) No. Discharges	(2) Concentration	(3) No. SNF
BPCI Participation for Joint Replacement	-1.76***	0.00	0.15
	[-2.63,-0.90]	[-0.03,0.04]	[-0.04,0.34]

Notes: Marginal effect significant at *p<0.05, **p<0.01, ***p<0.001; results based on three separate models, regressing outcomes in each column on hospital characteristics, hospital fixed effects, and year fixed effects (not shown).

BPCI Participation	(1) Survey Rating	(2) Outcome Rating	(3) Staffing Rating	(4) RN Staffing Rating
Average Marginal Effect	0.08*	0.16***	-0.03	-0.06
95% Confidence Interval	[0.01,0.16]	[0.10,0.22]	[-0.09,0.03]	[-0.11,0.002]

Notes: Average marginal effect significant at *p<0.05, **p<0.01, ***p<0.001; results shown based on 4 separate Poisson regression models (1 for each SNF quality measure) regressing a given patient's SNF quality on hospital fixed effects, year fixed effects, and hospital characteristics weighted by the inverse of the number of discharges per hospital

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