Attribution methods and implications for measuring performance in health care

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Purpose of the commissioned paper

This paper was commissioned by the National Quality Forum to identify and evaluate current attribution models in health care. This paper served as a foundation to inform the deliberations of a multi-stakeholder committee that will provide input and recommendations related to the use of attribution models in health care.

Attribution models are pre-specified rules that determine the specific patients, types of health care services, and the duration of care for which providers and organizations are responsible. Attribution of patients to providers is necessary to link indicators of patient-level health care quality and spending to specific providers for the purpose of profiling and accountability.

We conducted an environmental scan to identify the attribution models that are currently in use, as well as those that have been proposed but not implemented. These include retrospective and prospective attribution, whole and partial attribution, attribution for acute and chronic episodes, and primary care based and specialty-agnostic models. We will then discuss the challenges related to attribution and consider the relative merits of alternative attribution models. In addition to assessing the technical issues related to attribution, we consider the implications for using alternative approaches in the context of various programs – such as Accountable Care Organization programs and value-based payment – and payment modalities (e.g. fee-for-services and capitation). We will conclude with an assessment of the fit between current attribution models and programmatic needs, and how models may be revised to better meet these needs.

Definitions

- **Attribution**: pre-specified rules that determine the specific patients, types of health care services, and duration of care for which providers and organizations are responsible
- **Assignment**: used synonymously with "attribution"
- **Aggregation**: the combination of units at a lower level (e.g. individual provider) to a higher level (e.g. provider organization). Attribution is a necessary condition for aggregation.
- **Allocation**: The division of a performance indicator across different health care providers. For instance, 60% of health care spending may be allocated to Provider A and 40% is allocated to Provider B.
- **Quality of care:** In this paper, we will consider quality broadly, based on a modified version of Institute of Medicine's aims for health care: safety, timeliness, effectiveness, equity, and patient-centeredness.
- **Health care resource use**: Measures of health care utilization. Distinguished from measures of spending through the use of standardized prices.
- **Health care spending**: Measures total health care spending, including total resource use and unit price(s), by payer or consumer, for a health care service or group of health care services associated with a specified patient population, time period, and unit(s) of clinical accountability.
- **Providers**: denotes clinicians without regard to degree (e.g. registered nurses, licensed practical nurse, primary care physician, specialist physician, hospitals, post-acute care facilities, etc.)

Section 1. Introduction

The current health policy environment has made attribution – the methods used to assign patients to providers for the purpose of accountability – critical. Patients often receive care from numerous providers. Providers have historically lacked accountability for managing patients across the continuum of care. The resulting system-failures from poorly coordinated care are perceived to be responsible for many of the spending and quality problems in the United States.

New system reforms are trying to change this. Accountability programs require a set of rules to define which patients or episodes will "count" for which providers. Some of the most notable are the Accountable Care Organization (ACO) programs that have been initiated by the Centers for Medicare and Medicaid Services. These programs make groups of provider organizations that voluntarily choose to be part of the ACO responsible for the total spending and quality performance of traditional Medicare beneficiaries.

ACO payment models require a method to attribute patients to a particular ACO for the purpose of accountability. A common model attributes patients exclusively to the ACO that provides the plurality of primary care services from primary care physicians. Another possible model would attribute patients to the ACO that provides the plurality of any services by any provider. The first approach will only attribute patients to an ACO that includes primary care primary care providers. With more primary care providers, more patients would be attributed. The second approach could attribute patients to ACOs without primary care providers. The profound implications of these two models highlight the importance of attribution methods.

Attribution models matter beyond the ACO programs. Other accountability programs, such as the Physician Value-Based Payment Modifier and the soon-to-be-implemented Merit Based Incentive Payment System (MIPS) require attribution for the purpose of profiling physicians and group practices. Attribution is also critical in determining the hospitals and providers that will be accountable for care in the the new episode payment programs. Attribution is most relevant in circumstances in which accountability has not been clearly defined (e.g. ambulatory care in fee-for-service medicine).

Attribution can range from being relatively straightforward (e.g. for hospital inpatient episodes), to moderately challenging, (e.g. 30/60/90 post-discharge episodes), to highly challenging and controversial (e.g. chronic disease management). Crucially, the implications of alternative attribution methods have not been rigorously evaluated and the field has not coalesced around best practices for attribution. Instead, logical approaches have been developed based on previous methods. For instance, the approaches to attribution in the Medicare ACO programs were similar to those in the Physician Group Practice Demonstration.

To identify best practices for attribution, we must catalogue current approaches, identify criteria to assess their merits, and evaluate extant approaches with respect to appropriate clinical and programmatic contexts.

Section 2. Contextual factors and terms of attribution

Attribution can occur for different types of patients treated under different clinical circumstances by different types of providers. The resulting attribution can be for individual providers, provider organizations, or groups of larger providers. Attribution can cover a narrow or broad set of services. The duration under which an attributed provider is accountable for a given patient can also vary. Our conceptual model (Figure 1) contends that appropriate attribution should be determined based on the type of patient, the clinical circumstances, and the provider(s) delivering care. These combinations of factors will lead to a patient being attributed to a certain provider (or providers), for a specific duration.

Different types of patients may merit different attribution strategies. While a default rule could attribute patients to primary care physicians, patients with specific chronic diseases (e.g. end-stage renal disease) should perhaps be attributed to certain specialists (e.g. end-stage renal disease) should perhaps be attributed to certain specialists (e.g. nephrologists). Alternatively, attribution rules could make older patients more likely to be attributed to geriatricians or other specialists. The level of attribution (e.g. individual provider, provider organization, ACO) may affect the reliability and validity of performance measurement, as well as the incentives for accountability. Attribution rules may also seek to accommodate treatment patterns for patients in rural and urban areas. For instance, if a patient in a rural area receives extensive care at a tertiary care facility that is a substantial distance from the patient's residence, should an attribution algorithm preferentially attribute the patient to a local physician or practice?

The clinical circumstances surrounding the attribution of patients to providers may also be relevant. For instance, for attribution of acute events (e.g. 90-day episode following hip or knee replacement), the standard practice is to attribute patients to a hospital based on an "index hospitalization." The index hospitalization is defined by the first hospitalization that initiates an episode: another hospitalization occurring within 30-days of the index hospitalization typically does not initiate a new episode. Thus, temporal precedence matters. However, for chronic care, attribution models, temporality has not typically mattered. Instead, patients are typically attributed to the physician providing the highest frequency or intensity of care for that chronic condition.

The providers whose care contributes to attribution is also relevant. On one hand, only primary care providers could contribute to attribution decisions. Alternatively, any provider could contribute to an attribution decision. In between, non-primary care providers could contribute to attribution only when a patient was not cared for by a primary care provider. The latter example provides a framework for customized attribution rules. These rules could hold that, optimally, certain patients should be attributed to certain providers under certain circumstances. If these conditions are not met, then attribution could default to a generic algorithm (e.g. plurality of primary care services).

After attribution occurs, the terms of accountability care vary across a number of dimensions. These include the type of services for which a provider is accountable (e.g. only care related to diagnostically defined episode, all care occurring within episode); duration of episode (e.g. 30 days, 90 days, one year, multiple years).

One final issue relevant to attribution concerns the data elements that are required. Medical claims are the most commonly used data source for attribution. Electronic health record data are an alternative, but imperfect given the priority of including data from providers from different organizations in attribution and the lack of interoperability of many EHRs. Patient/provider/payer designation or attestation could also be used for attribution, but would likely be most relevant for prospective attribution approaches.

Section 3. Environmental scan of attribution approaches

We performed an environmental scan to identify the attribution methods that have been proposed or are currently in use for accountability applications in health care. Initially, we pursued a search strategy using a variety of key words and MESH headings such as (attribut*[Title/Abstract] OR assign*[Title/Abstract]) AND(("Insurance, Health, Reimbursement"[Majr]) OR ("Accountable Care Organizations"[Majr]) OR ("Cost Control"[Majr]). However, this strategy was too sensitive and not sufficiently specific: it identified large numbers of irrelevant articles while failing to generate results that spanned all situations in which attribution is applicable. For instance, the strategy query detailed above produced 658 hits; yet it would have been unlikely to pick up articles describing the attribution of episode of care to providers. Queries resulting in more comprehensive searches, however, yielded over 2000 results. To address this issue, we employed a "snowball" search strategy in which we identified 15 highly relevant sources that described attribution and/or present different attribution models for a variety of purposes including accountable care organizations, physician profiling, and pay-for-performance programs (Figure 2). We used Google Scholar to identify publications that have cited these papers and then reviewed the hits for sources that outline one or more attribution models. We also searched the bibliographies of the initial 15 sources to identify additional relevant publications (Figure 3). No exclusions were made in either component of the search process based on the date of publication, location of study, or type of resource. As a result, our search generated a variety of materials including original research articles, editorials, and reports. To supplement our main search strategy, we used PubMed and Embase to identify additional examples of attribution models. The exact search terms and the results are outlined in Figure 4. This search uncovered 8 additional attribution models.

Overall, our environmental scan identified 84 sources describing 171 unique attribution models that have been proposed or are currently being used in accountability programs (Table 4 and Table 5). Attribution models were categorized by the following characteristics: 1. Clinical circumstances; 2. Type of provider attributed; 3. Payer/programmatic circumstances; 4. Timing of attribution (retrospective vs. prospective); 5. Exclusivity of attribution (single vs. multiple provider); 6. Period of time of which providers are accountable for attributed patients; 7. Minimum requirement to make an attribution (such as a plurality or a majority); and 8. Measure used in attribution process (such as spending or visits) (Table 1). Due to the absence of information in the descriptions of some attribution models, several assumptions were made during the process of identifying model characteristics. For instance, it was assumed that approaches using claims data were retrospective unless explicitly stated otherwise. Another common assumption made in the absence of information regarding exclusivity of attribution was that approaches with either a plurality or a majority rule would attribute patients to a single

provider. For models tied to previously or currently implemented accountability programs, we cross-referenced outside sources in cases in which the descriptions found during the literature review were highly ambiguous. Even after taking these steps, some models were difficult to characterize because they involved multiple steps and/or varying approaches for different patients.

Table 1 shows the characteristics of attribution approaches that were identified in the environmental scan (n=171). Of these approaches, 82.5% have been proposed but not implemented in a formal program and 17.5% have been implemented. Attribution to "any physician" was the most common type or provider attributed (48.5%), followed by attribution to primary care providers (PCPs) (15.8%). Most approaches employed retrospective attribution (88.9%) rather than prospective attribution (6.4%). Attribution approaches tended to focus on all care (45.6%) or care for particular episodes (39.2%). Most of the attribution models were studied among Medicare (43.3%) or commercially insured patients (32.7%). Attribution approaches tended to require attribution to only one provider (77.8%) rather than to multiple providers (19.3%). Visits (42.7%) and spending (30.4%) were the most common measures used to attribute patients to providers. However, the use of other approaches was also common (24.6%) and included approaches such as attributing patients based on their provider enrollment status. There was considerable variation with respect to the minimum criteria required for attribution: a plurality was the most common criteria (29.8%). Specific thresholds were enforced in 28.1% of approaches. Several (19.3%) models used other approaches. For examples, for some attribution models that spanned all programmatic circumstances, criteria varied depending on whether beneficiaries were enrolled with a physician as part of their health plan. The period of time for which the provider was responsible for attributed patients varied considerably across the models and in many cases the time period was not specified in model descriptions (39.2%). When duration was specified, the most common approach was to attribute patients for one year (29.2%). Other approaches such as the attribution of patients for the duration of an episode were also common (24.6%).

Table 2 shows the same set of characteristics of attribution approaches that were identified in the environmental scan among the implemented models (n=30). Compared to the characteristics of both the implemented and proposed models shown in Table 1, a greater share of the implemented models: were for ACOs (43.3% of implemented versus 10.5% of all); used prospective attribution (23.3% of implemented versus 6.4% of all); applied to all health care services (66.7% of implemented versus 45.6% of all); and were payer agnostic (30.0% of implemented versus 17.0% of all). The characteristics of implemented and all attribution models were similar with respect to exclusivity of attribution, the measures used for attribution, the minimum requirement for attribution, and the period of time over which attributed providers were responsible for attributed patients.

Table 3 shows the bivariate relationship between the type of attributed provider (ACO; any physician/physician group; and PCPs) and the characteristics of attribution approaches (n=149). It shows that attribution models that were applied to ACOs were more likely to use prospective attribution (38.9%), were some somewhat more likely to make attribution on the basis of the plurality of care (44.4%), and more likely to require accountability for one year (44.4%).

Section 4: Discussion

Challenges Related to Attribution

Many of the challenges surrounding attribution are related to the high dispersion of health care in the United States. Medicare patients see a median of two PCPs and five specialists that are associated with for four different provider organizations in one year (Pham et al. 2007). The attribution of a patient to a provider implies that the provider is responsible for the care and/or influences the health outcomes of that patient. Providers are not inherently equal in their roles in patient care even when they have similar levels of contact with patients. Because of this, it is often uncertain how to determine which patients should be attributed and which should be excluded. The issue of care dispersion creates additional challenges when selecting an appropriate method to attribute patients to providers.

Attribution approaches should be simultaneously reliable and valid. When large numbers of patients are attributed to providers, performance measures are more reliable, increasing the ability to distinguish performance across providers. However, because care is highly dispersive, choosing attribution approaches based on their ability to result in a large n for each provider risks including patients that only receive a small portion of care from a provider. This in turn can compromise the validity of the attribution process. Attribution methods must strike a balance of attributing enough patients and attributing patients for which providers are responsible.

Attribution approaches should also be fair and equitable to both patients and providers. Attribution approaches that are closely aligned with how providers feel they are responsible for patients are more likely to be perceived as fair. In a system of highly coordinated care, attribution can more easily be designed to reflect the ways in which care is already being provided and therefore may be more favorable to providers. However, when patients receive care from multiple physicians and provider organizations, an attribution approach can instead be used as a tool to incentivize desirable system outcomes such as greater care coordination. In this case, some unfairness in the approach is expected simply because providers will not have full control over patient outcomes. What is initially unfair can be transformed into an approach that is fair once providers implement systematic changes in the delivery of care. Yet, when attribution is used in this way, there is a tremendous challenge in devising an approach that pushes providers to make changes without being perceived as entirely out of reach. The different aspects of attribution models attempt to mitigate the challenges of linking patients to providers while being fair, reliable, and valid.

Strengths and Weaknesses of Different Attribution Approaches

Attribution approaches may involve linking patients to individual physicians or groups such as ACOs or hospitals. One of the advantages of assigning patients to larger units is that more patients can be attributed and thus estimates of provider performance can be more reliable (Fisher et al. 2006). Yet, because care can be dispersed across different groups of providers, this approach does not completely eliminate the challenge of accurately representing providers' patient populations.

Approaches that assign patients to physicians may further specify the type of physician that to which patients can be attributed. Although for some clinical circumstances the choice of physician can be

based on the type of service provided, attribution is more complicated for accountability programs assessing the delivery of primary care. Primary care is not always delivered by physicians that are typically defined as PCPs such as internists, generalists, and family medicine practitioners. As a result, some approaches will attribute patients to specialists, but the merits of this strategy as well as whether patients should be attributed to individuals or groups largely depend on the purposes of an accountability program. While empirical evidence does not currently support the relative merits of attribution approaches, rigorous justification of the elements of attribution models would likely enhance attribution choices.

Retrospective attribution has the advantage of making assignments based on how care is actually delivered, but has the disadvantage that providers do not who counts as their patients until after they have already provided care. Prospective attribution approaches remove uncertainty on the part of the provider. On one hand, from the perspective of providers, this may be fairer, but it also introduces the possibility of gaming or providing differential levels of care to patients based on attribution status. In the models using prospective attribution, even if patients are informed of their physician assignments, they are not precluded from seeking care outside of their designation. As a result, prospective attribution may lead to inaccurate representations of the care that providers actually provide. Although the vast majority of attribution models uncovered in our environmental scan utilize retrospective attribution, the debate over the virtues of the two methods does not appear to be resolved. The Medicare Shared Saving Program was originally designed to involve retrospective attribution, but has since implemented different programs tracks, some of which incorporate prospective attribution (Baseman et al. 2016). The provision of lists of patients that will likely be attributed to providers at the beginning of the measurement period is one approach that attempts to mitigate the uncertainty involved in retrospective attribution.

Most attribution models identified through the environmental scan involve all clinical circumstances (including primary care) or episodes of care rather than the attribution of acute or chronic care. Using episodes of care in the attribution process is advantageous in that care within an episode may be more highly concentrated among an individual physician or provider group (Damberg et al. 2009). In addition, there may be more clarity about the roles of different providers within an episode, making attribution more straightforward. Despite these benefits, episodes of care are limited in their applications and cannot be applied to all circumstances such as primary care or chronic conditions in which episodes are hard to define. Attribution to primary care providers may be more appropriate for clinical circumstances that occur over long durations favor attribution to primary care providers, whereas specialist attribution may be preferred for episodes of shorter duration.

Attribution models vary in their exclusivity: whether patients are attributed to one provider or multiple providers. Given the highly dispersive nature of care, the attribution of a patient to a single provider may not be equitable because it may fail to attribute patients to providers that have significant involvement in their care. Attribution to multiple providers acknowledges that many patients receive care from more than one provider and may more accurately reflect providers' actual patient pools. This approach can potentially foster greater levels of accountability for all patients rather than only patients

with whom providers have established relationships. Nonetheless, the allowance of attribution to multiple providers was significantly less common among models uncovered in the environmental scan.

Incorporating requirements when making attributions attempts to ensure that patients are only attributed to providers that are responsible for their care. Higher thresholds such as majority or plurality rules are in some ways more favorable to providers because they restrict the attribution of patients with whom they have had limited contact. However, these rules may result in the attribution of fewer patients while excluding some that providers would consider as patients. As a result, requirements that are too strict may compromise the reliability of an approach. Overall, the appropriate requirement depends on what is being measured in an accountability program. For example, a PCP treating a diabetic patient should follow certain clinical guidelines regardless of how many times he/she has seen a patient; however, attributing outcomes to a PCP who has seen a patient once may be unfair. In general, incorporating a majority rule may be appropriate for programs in which outcomes are assessed, but a one-touch rule may be more appropriate for an accountability program relying more on care that can be managed over a shorter interval. In some circumstances, it may also be fair to make providers responsible for care that occurs outside of their direct influence.

In conjunction with minimum requirements, many attribution approaches incorporate a specific measure to define greater involvement in patient care. The environmental scan revealed that visits and spending are the two most common measures used in this way. Although both are proxies for assessing the level of responsibility and influence of a provider on a patient, neither is necessarily proportional in terms of their impact on patient care. Visits, for example, can have different values for patients depending on the purpose and the services provided. In addition, spending disproportionately favors the attribution of patients to specialists even though they may have had limited involvement in the clinical decisions that led to spending (Leapfrog 2004). In an attempt to mitigate this challenge, a few models uncovered in the scan incorporated the attribution of Medicare patients using relative value units (RVUs) (Lake 2007; Weiner 1995). Although RVUs differentiate services according to their resource intensity, this approach may be less straightforward and would be unlikely to fully address the disadvantages of using visits or spending.

Finally, attribution approaches also vary in terms of the length that patients are assigned to providers. Because more care is provided as time goes on, longer time periods increase the ability to identify patterns of care and link patients to providers that have more involvement in their care. Longer patient-provider relationships may indicate greater levels of responsibility and setting attribution lengths in this way may also encourage this form of care. Increasing the time period can also increase the number of patients that are assigned to providers, and thus increase the likelihood that attributed patients reflect their patient pool (AcademyHealth). However, because patients may not consistently see the same providers over longer periods of time, periods that are too long also introduce the risk of attributing patients that have only received low levels of care. Pham et al found that only 67% of patients were attributed to the same provider in the subsequent year.

Lessons from Attribution in Education

Much like health care, efforts to increase the quality of education in the United States have relied on accountability programs such as merit pay incentives and school performance rating programs. Although linking students to teachers or schools may seem fairly straightforward given the inherent enrollment process involved in education, attribution in education suffers from many of the same challenges as health care. For one, many students have more than one teacher for a single subject in a given year. Students may switch schools both within and between years. In addition, because academic gains are made over time and the effect of an individual teacher may not be immediate, attributing scores to a teacher who taught a student for one month might be unreasonable. Yet, there is no clear amount of instruction time a student must receive with a teacher to make an attribution fair. Further complicating attribution, a student's performance is influenced both by his/her previous teachers and current teachers of other subjects. As a result, a fifth grader's math scores could not only be attributed to the student's fifth grade math teacher but also other teachers like his/her fourth grade math and fifth grade English teachers. Different accountability programs have used various approaches in an attempt to address these challenges.

Pennsylvania Value Added Assessment System

The Pennsylvania System of School Assessment is a program that rates teachers and schools according to their impact on students' academic progress. As part of this program, teachers verify preliminary student rosters to ensure that all students are accurately attributed to teachers. Each individual student is then weighted according to the percent of instructional responsibility. This value takes into consideration the percent of days a student is enrolled in a teacher's class and the percent of content within a course that the teacher is responsible for (PVAAS 2014).

Denver Public Schools' Exceeds Expectations Program

The Exceeds Expectations Program is a system that awards bonuses to teachers on the basis of student growth percentiles. Students are attributed to teachers if they are enrolled for at 85% of a course and in attendance at least 85% of the time. This approach was implemented in an effort to exclude students who have not had sufficient amounts of instructional time with teachers (CDE).

Tennessee Teacher Evaluation System

The Tennessee Teacher Evaluation System is an accountability program uses a value-added approach to assess the impact of teachers on students' achievements. Students who are enrolled with a teacher for 150 days per year have 100% of their performance attributed to that teacher. Students who are enrolled for 75-149 days have 50% of their performance attributed to that teacher. Students enrolled for less than 75 days are not attributed to a teacher (Steele et al. 2010).

The strategy of using thresholds in both the Denver and Tennessee approaches mirrors that in health care. However, none of the models uncovered in the environmental scan use the partial or weighted attribution of patients to providers. Although determining how to weight patients would be challenging in practice, this strategy does have potential applications in health care. Incorporating the idea that some patients continuously receive the majority of their care from a single physician and thus should be

weighed more heavily than those who visit a provider once may help address some concerns surrounding current attribution approaches.

Improving Attribution in health care

There is a no single attribution approach that best meets the needs of all accountability programs. Factors such as the interests of the stakeholders, aims of the accountability program, and clinical circumstances influence the appropriateness of an attribution approach. The models identified through the environmental scan portray both the variety as well as the similarities in ways that approaches have been devised to address the uncertainty and instability in attribution. Although any attribution approach will inherently involve making tradeoffs, certain steps should be taken to improve current attribution models:

Data

Current attribution methods could benefit from better data surrounding the relationship between patients and providers. This will increase the ability of attribution methods to reflect the ways in which care is delivered as well as the ability to select measures that are useful in the attribution process. Due to the limits in information, many models use proxies to make links between physicians and providers. For example, it is common among attribution approaches use tax identifiers to differentiate between physicians or providers. Yet, physicians frequently bill under multiple tax identifiers and/or bill under tax identifiers that are at a group level, precluding the attribution of patients to individual providers (Damberg et al. 2009). Understanding the flaws of current methods as well as looking for appropriate alternatives can help strengthen attribution approaches.

Standardization

Even though the consistency of attribution approaches across all accountability programs is impractical, certain elements could be standardized. For example, several attribution models are designed around evaluation and management visits; however, there is no consistent definition of what counts as such (Damberg et al. 2009). Ensuring some standardization may increase clarity among providers and may also increase the ability to evaluate the effect of differences in attribution approaches as they are applied.

Patient and Provider Engagement

Attribution approaches could be improved by increasing the engagement of patients and providers. This includes not only incorporating their perspectives in the selection of a method, but also informing them of the details involved in the chosen method. The perspective on which approach is the best varies based on the interests of the stakeholders involved (Mehrotra et al. 2010). By engaging with patients and providers, accountability programs may be better positioned to balance competing interests and increase the responsiveness to programs.

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Figure 1. Conceptual Model of Attribution

- Level of attribution
- Specific provider(s)
- For a specific set of services
- For a specific duration
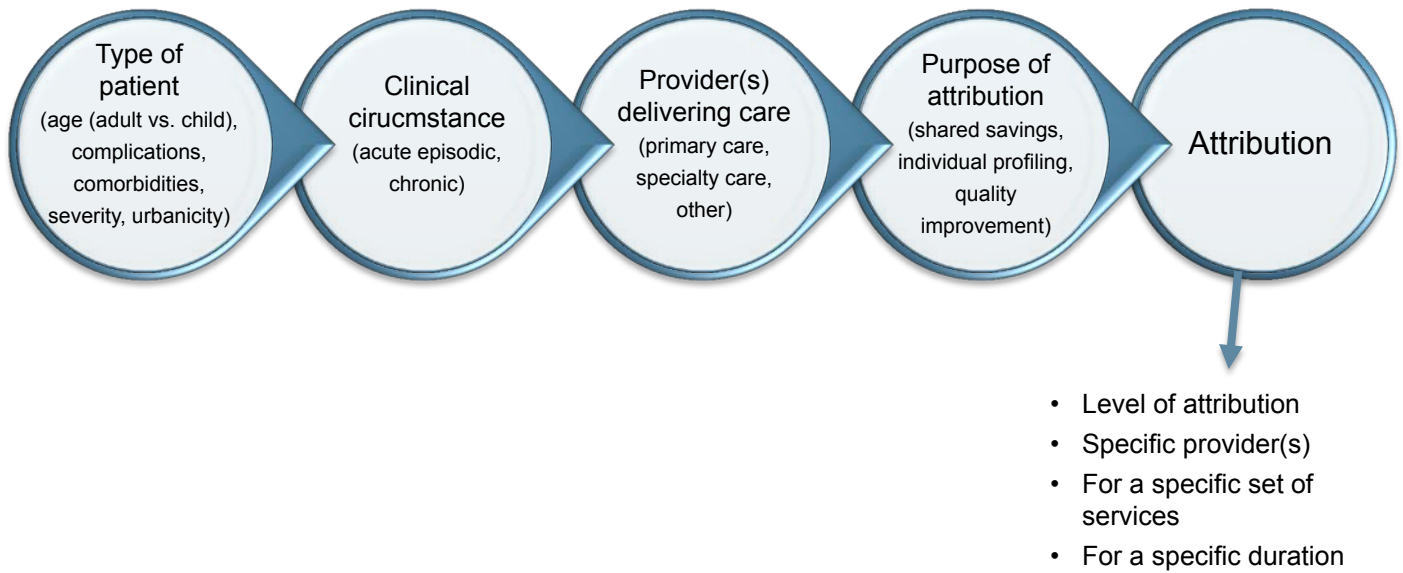
Figure 2. Schematic of Search Strategy 1: Search Reference Lists of relevant articles

15 Articles Selected: Describe attribution in different settings and/or specific attribution models

↓

373 Articles:
References for at least one of the 15 articles

→

83 Articles Excluded:
67 Duplicates- References for more than one of the original 15 articles
9 - Same as originals
7 - Cited and reference

↓

290 Articles Selected for Title and Abstract Review

→

253 Articles Excluded:
Non-English - 2
Not involving attribution - 251

↓

37 Articles Selected for Detailed Review

→

19 Articles Excluded:
Not describing a specific attribution model

↓

18 Articles Describing Attribution Models

Figure 3. Schematic of Search Strategy 2: Search articles that cited relevant articles

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┌─────────────────────────────────┐
│  15 Articles Selected: Describe  │
│ attribution in different settings │
│   and/or specific attribution    │
│            models                │
└─────────────────────────────────┘
                │
                ▼
┌─────────────────────────────────┐
│        862 Articles:             │
│  Cited at least one of the 15    │
│           articles               │
└─────────────────────────────────┘
                │                         ┌─────────────────────────────────┐
                ├────────────────────────▶│      94 Articles Excluded:       │
                │                         │  Duplicates - cited more than    │
                │                         │  one of the original 15 articles │
                ▼                         └─────────────────────────────────┘
┌─────────────────────────────────┐
│ 768 Articles Selected for Title  │
│      and Abstract Review         │
└─────────────────────────────────┘
                │                         ┌─────────────────────────────────┐
                ├────────────────────────▶│      632 Articles Excluded:      │
                │                         │       Original Articles - 8      │
                │                         │        Non-English - 34          │
                │                         │  Not involving attribution - 610 │
                ▼                         └─────────────────────────────────┘
┌─────────────────────────────────┐
│ 116 Articles Selected for        │
│       Detailed Review            │
└─────────────────────────────────┘
                │                         ┌─────────────────────────────────┐
                ├────────────────────────▶│      64 Articles Excluded:       │
                │                         │   Not describing a specific      │
                │                         │      attribution model           │
                ▼                         └─────────────────────────────────┘
┌─────────────────────────────────┐
│ 52 Articles Describing           │
│      Attribution Models          │
└─────────────────────────────────┘
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Figure 4: Schematic of supplemental search strategy: Search PubMed and Embase

PubMed: 268 Hits

(attribut*[Title/Abstract]) OR assign*[Title/Abstract]) AND (delivery of health care[MeSH: noexp] OR quality of health care[MeSH: noexp] OR health care costs[MeSH: noexp] OR practice patterns, physicians[MeSH:noexp]) AND (accountable care organization*[Title/Abstract] OR value based purchasing[Title/Abstract] OR pay for performance[Title/Abstract] OR public report*[Title/Abstract] OR episode[Title/Abstract] OR profil*[Title/Abstract] OR tier*[Title/Abstract])

Embase: 944 Hits

attribut*:ab,ti OR assign*:ab,ti AND ('health care delivery'/de OR 'health care quality'/de OR 'health care cost'/de OR 'clinical practice'/de) AND ('accountable care organization':ab,ti OR 'value based purchasing':ab,ti OR 'pay for performance':ab,ti OR 'public report*':ab,ti OR episode:ab,ti OR profil*:ab,ti OR tier*:ab,ti)

222 Articles Excluded: Duplicates and/or Previously Reviewed

990 Articles Selected for Title Review

909 Articles Excluded: Non-English - 39 Not involving attribution - 870

81 Articles Selected for Detailed Review

67 Articles Excluded: Not describing a specific attribution model

14 Articles Describing Attribution Models

Table 1. Characteristics of approaches to attribution described in environmental scan (n=171)

Characteristic	Elements	N	Percentage
Program stage	Implemented	30	17.5%
	Proposed	141	82.5%
Type of provider attributed	ACO	18	10.5%
	Any physician	83	48.5%
	Hospital (Facility, clinic)	13	7.6%
	Other	5	2.9%
	PCP	27	15.8%
	PCP preferred	6	3.5%
	Physician group	15	8.8%
	Specialist	3	1.8%
	Unknown	1	0.6%
Timing of attribution	Other	8	4.7%
	Prospective	11	6.4%
	Retrospective	152	88.9%
Clinical Circumstances	All care	78	45.6%
	Chronic	20	11.7%
	Episodic	67	39.2%
	Other	6	3.5%
Payer/programmatic circumstances	Payer agnostic	29	17.0%
	Commercial payer	56	32.7%
	Demonstration	1	0.6%
	Medicaid	2	1.2%
	Medicare	74	43.3%
	Other	9	5.3%
Exclusivity of attribution	Patient is attributed to multiple providers	33	19.3%
	Patient is attributed to only one provider	133	77.8%
	Unknown	5	2.9%
Measure used to make attribution	Spending	52	30.4%
	Enrollment	2	1.2%
	Other	42	24.6%
	Unknown	2	1.2%
	Visit	73	42.7%
Minimum requirement to make attribution	Majority of care	24	14.0%
	"One Touch"	13	7.6%
	Other	33	19.3%
	Plurality of care	51	29.8%
	Plurality of care with Threshold (ex. 30%, 2 visits)	20	11.7%
	Threshold	28	16.4%
	Unknown	2	1.2%
Period of time for which provider is responsible for attributed patients	More than 1 year	50	29.2%
	One year	42	24.6%
	Other	67	39.2%
	Unknown	12	7.0%

Table 2. Characteristics of approaches to attribution described in environmental scan from implemented models (n=30)

Characteristic	Elements	N	Percentage
Program stage	Implemented	30	100.0%
	Proposed	0	0.0%
Type of provider attributed	ACO	13	43.3%
	Any physician	8	26.7%
	Hospital (Facility, clinic)	1	3.3%
	Other	2	6.7%
	PCP	1	3.3%
	PCP preferred	3	10.0%
	Physician group	2	6.7%
	Specialist	0	0.0%
	Unknown	0	0.0%
Timing of attribution	Other	4	13.3%
	Prospective	7	23.3%
	Retrospective	19	63.3%
Clinical circumstances	All care	20	66.7%
	Chronic	0	0.0%
	Episodic	8	26.7%
	Other	2	6.7%
Payer/programmatic circumstances	Payer agnostic	9	30.0%
	Commercial payer	13	43.3%
	Demonstration	1	3.3%
	Medicaid	2	6.7%
	Medicare	3	10.0%
	Other	2	6.7%
Exclusivity of attribution	Patient is attributed to multiple providers	4	13.3%
	Patient is attributed to only one provider	24	80.0%
	Unknown	2	6.7%
Measure used to make attribution	Spending	8	26.7%
	Enrollment	2	6.7%
	Other*	9	30.0%
	Unknown	0	0.0%
	Visit	11	36.7%
Minimum requirement to make attribution	Majority of care	3	10.0%
	"One Touch"	2	6.7%
	Other**	9	30.0%
	Plurality of care	10	33.3%
	Plurality of care with Threshold (ex. 30%, 2 visits)	3	10.0%
	Threshold	2	6.7%
	Unknown	1	3.3%
Period of time for which provider is responsible for attributed patients	More than 1 year	2	6.7%
	One year	9	30.0%
	Other***	11	36.7%
	Unknown	8	26.7%

Notes: * Some examples of "other" measures include: Attribution was made based on unspecified "services"; For some attribution models that spanned all programmatic circumstances, the measure used varied depending on whether beneficiaries were enrolled with a physician as part of their health plan; The model prioritized using either spending or visits to make an attribution, but used the other to resolve ties between two or more providers.

** Some examples of "other" minimum requirements include: Patients were enrolled with or designated a provider; For some attribution models that spanned all programmatic circumstances, the requirement used varied depending on whether beneficiaries were enrolled with a physician as part of their health plan

***The majority in the "other" category involved the attribution of episodes, in which case the duration of the attribution was dependent on the duration of the episode. A small number of models attributed patients for less than one year

Table 3. Bivariate relationship between attributed providers and characteristics of approaches to attribution for select attributed providers (n=149)

Characteristic	Elements	ACO N	ACO Percentage	Any physician/ group N	Any physician/ group Percentage	PCP/ PCP preferred N	PCP/ PCP preferred Percentage
Program stage	Implemented	13	72.2%	10	10.2%	4	12.1%
	Proposed	5	27.8%	88	89.8%	29	87.9%
Timing of attribution	Other	2	11.1%	2	2.0%	3	9.1%
	Prospective	7	38.9%	2	2.0%	1	3.0%
	Retrospective	9	50.0%	94	95.9%	29	87.9%
Clinical Circumstances	All care	13	72.2%	34	34.7%	24	72.7%
	Chronic	0	0.0%	10	10.2%	4	12.1%
	Episodic	3	16.7%	53	54.1%	4	12.1%
	Other	2	11.1%	1	1.0%	1	3.0%
Payer/programmatic circumstances	Payer agnostic	0	0.0%	17	17.3%	10	30.3%
	Commercial payer	8	44.4%	37	37.8%	9	27.3%
	Demonstration	0	0.0%	1	1.0%	0	0.0%
	Medicaid	2	11.1%	0	0.0%	0	0.0%
	Medicare	7	38.9%	41	41.8%	12	36.4%
	Other	1	5.6%	2	2.0%	2	6.1%
Exclusivity of attribution	Patient is attributed to multiple providers	0	0.0%	23	23.5%	7	21.2%
	Patient is attributed to only one provider	16	88.9%	74	75.5%	26	78.8%
	Unknown	2	11.1%	1	1.0%	0	0.0%
Measure used to make Attribution	Spending	3	16.7%	41	41.8%	2	6.1%
	Enrollment	1	5.6%	0	0.0%	0	0.0%
	Other	9	50.0%	14	14.3%	10	30.3%
	Unknown	0	0.0%	1	1.0%	0	0.0%
	Visit	5	27.8%	42	42.9%	21	63.6%
Minimum requirement to make attribution	Majority of care	1	5.6%	17	17.3%	5	15.2%
	"One Touch"	1	5.6%	8	8.2%	4	12.1%
	Other	6	33.3%	8	8.2%	10	30.3%
	Plurality of care	8	44.4%	28	28.6%	10	30.3%
	Plurality of care with Threshold (ex. 30%, 2 visits)	0	0.0%	16	16.3%	1	3.0%
	Threshold	0	0.0%	21	21.4%	3	9.1%
	Unknown	2	11.1%	0	0.0%	0	0.0%
Period of time for which provider is responsible for attributed patients	More than 1 year	1	5.6%	25	25.5%	18	54.5%
	One year	8	44.4%	24	24.5%	8	24.2%
	Other	6	33.3%	47	48.0%	4	12.1%
	Unknown	3	16.7%	2	2.0%	3	9.1%

Note: Table does not include data from attributed hospitals, specialists, other providers, or unknown providers

Table 4. Summary of attribution approaches from implemented models identified in the literature search

Accountability Program	Description	Attribution Method	Related References
Accountable Care Organizations			
Alternative Quality Contract	A global payment contract for beneficiaries enrolled in Blue Cross Blue Shield of Massachusetts	Beneficiaries are prospectively attributed to a PCP by designating their PCP at the beginning of each year.	Song Z. Payment Reform in Massachusetts: Health Care Spending and Quality in Accountable Care Organizations Four Years into Global Payment. 2014. Doctoral Dissertation, Harvard University Medical School.
Children's Hospital and Clinics (CHC) of Minnesota	Medicaid ACO in the Twin Cities exclusively serving pediatric patients	Patients are retrospectively attributed to CHC based on: 1. whether they are in a healthcare home; or 2. where they received the plurality of their primary care.	1. Christensen EW, Payne NR. Effect of Attribution Length on the Use and Cost of Health Care for a Pediatric Medicaid Accountable Care Organization. JAMA Pediatr. 2016;170(2):148. doi:10.1001/jamapediatrics.2015.3446.; 2. Gleeson S, Brilli R. Does the Medical Home Really Matter? J Pediatr. 2016; 170: 14-16.
HealthCare Partners	Pilot ACO program for Anthem beneficiaries in California	Episodes are attributed to an ACO based on the plurality of allowed charges to either a primary care physician or a specialist. Attributions are also made prospectively based on historical care patterns- specifically, the plurality of outpatient evaluation and management visits.	Larson BK, Van Citters AD, Kreindler SA, et al. Insights from transformations under way at four Brookings-Dartmouth accountable care organization pilot sites. Health Aff (Millwood). 2012;31(11):2395-2406. doi:10.1377/hlthaff.2011.1219.; See also: Gbemundo JN, Larson BK, Van Critters AD, et al. HealthCare Partners: Building on a Foundation of Global Risk Management to Achieve Accountable Care. The Commonwealth Fund. 2012. Retrieved from http://www.commonwealthfund.org/~/media/Files/Publications/Case%20Study/2012/Jan/1572_Gbemudu_HealthCare_Partners_case%20study_01_17_2012.pdf.
Medica	A regional health plan based in Minnesota that operates a shared savings contract	Patients are retrospectively attributed to a care system if they received 50% of primary care services from that system. Primary care is defined by place of service (office visits, or for those in the Medicaid product, emergency department visits) and the provider's specialty (internal medicine, general practice, family medicine, or OB/GYN).	Carlin C. Patient loyalty in a mature IDS market: is population health management worth it? Health Serv Res. 2014; 49(3): 1011-33.
Medicaid ACOs in Arkansas, Ohio, and Tennessee	Medicaid ACO programs	Episodes of perinatal care are retrospectively attributed to the health care provider who delivers a neonate. That provider is responsible for all perinatal care that occurred up to 40 weeks before delivery and care for 60 days postpartum.	Jarlenski M, Borrero S, La Charité T, Zite NB. Episode-based payment for perinatal care in medicaid. Obstet. Gynecol. 2016; 127(6):1080–84.
Medicare Shared Savings Program	Medicare ACO Program	A beneficiary is attributed to an ACO if the beneficiary receives the plurality of his or her primary care services from primary care practitioners (primary care physicians, nurse practitioners, clinical nurse specialists, physician assistants, or ACO professionals providing services at a FQHC/RHC) within the ACO.	1. Baseman S, Boccuti C, Moon M, Griffin S, Dutta T. Payment and Delivery System Reform in Medicare. Henry J. Kaiser Family Foundation. 2016. Retrieved from http://kff.org/medicare/ report/payment-and-delivery-system-reform-in-medicare-a-primer-on-medical-homes-accountable-care-organizations-and-bundled-payments/; 2. Hayen A. Incorporating shared savings programs into primary care: from theory to practice. BMC Heal Serv. 2015; 15:580.; See also: 1. Centers for Medicare and Medicaid Services. Medicare Shared Savings Program: Shared savings and losses and assignment methodology applicable beginning performance year 2016. CMS. 2015. Retrieved from https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/sharedsavingsprogram/Downloads/Shared-Savings-Losses-Assignment-Spec-V4.pdf 4; 2. MacKinney AC, Mueller KJ, Zhu X, Vaughn T. Medicare accountable care organizations: program eligibility, beneficiary assignment, and quality measures. Rural Policy Brief. 2014; 1–6.; This attribution model is applied and analzed in the following articles: 1. McWilliams JM, Chernew ME, Zaslavsky AM, Landon BE. 2013. Post-acute care and acos - who will be accountable? Health Serv. Res. 48(4):1526–38; 2. McWilliams JM, Chernew ME, Zaslavsky AM, Hamed P, Landon BE. 2013. Delivery system integration and health care spending and quality for medicare beneficiaries. JAMA Intern. Med. 173(15):1447; 3. Mukherji SK. 2014. The potential impact of accountable care organizations with respect to cost and quality with special attention to imaging. J. Am. Coll. Radiol. 2014; 11(4):391–96.
Monarch HealthCare	Pilot ACO program for Anthem beneficiaries in California	Episodes are attributed to an ACO based on the plurality of allowed charges to either a primary care physician or a specialist. Attributions are also made prospectively based on historical care patterns- specifically, the plurality of outpatient evaluation and management visits.	Larson BK, Van Citters AD, Kreindler SA, et al. Insights from transformations under way at four Brookings-Dartmouth accountable care organization pilot sites. Health Aff (Millwood). 2012;31(11):2395-2406. doi:10.1377/hlthaff.2011.1219.
Norton HealthCare	Pilot ACO program for Humana beneficiaries in Kentucky	Patients are prospectively attributed to an ACO based on historical care patterns. Specifically, an attribution is made based on the plurality of outpatient evaluation and management visits.	Larson BK, Van Citters AD, Kreindler SA, et al. Insights from transformations under way at four Brookings-Dartmouth accountable care organization pilot sites. Health Aff (Millwood). 2012;31(11):2395-2406. doi:10.1377/hlthaff.2011.1219.

Accountability Program	Description	Attribution Method	Related References
Pioneer ACO	Medicare ACO program	The exact attribution method varies among Pioneer ACOs, however, each involves prospective attribution. Physicians are provided a list of patients in their ACOs. In some cases, ACOs may submit attestations from beneficiaries regarding their desire to be attributed to a provider. Beneficiary confirmations will be reflected in ACO alignment in the subsequent performance year.	1. Baseman S, Boccuti C, Moon M, Griffin S, Dutta T. Payment and Delivery System Reform in Medicare. Henry J. Kaiser Family Foundation. 2016. Retrieved from http://kff.org/medicare/ report/payment-and-delivery-system-reform-in-medicare-a-primer-on-medical-homes-accountable-care-organizations-and-bundled-payments/; 2. Dowd B, Kane R, Parashuram S. Alternative approaches to measuring physician resource use final report. CMS. 2012. Retreived from https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/Reports/Downloads/Alt_Approaches_Measuring_Phys_Res_Use_Report.pdf.; 3. Hsu J, Price M, Spirt J, Vogeli C. Patient Population Loss At A Large Pioneer Accountable Care Organization And Implications For Refining The Program. Health Aff. 2016; 35(3)- 422-30. 4. MacKinney AC, Mueller KJ, Zhu X, Vaughn T. Medicare accountable care organizations: program eligibility, beneficiary assignment, and quality measures. Rural Policy Brief. 2014; 1–6; 5. McWilliams JM, Chernew ME, Landon BE, Schwartz AL. 2015. Performance differences in year 1 of pioneer accountable care organizations. N. Engl. J. Med. 2015; 372(20):1927–36; 6. Schwartz AL, Chernew ME, Landon BE, McWilliams JM. Changes in low-value services in year 1 of the medicare pioneer accountable care organization program. JAMA Intern. Med. 2015; 175(11):1815
Tucson Medical Center	Pilot ACO program for United HealthCare beneficiaries in Arizona	Patients are prospectively attributed based on historical care patterns—specifically, the plurality of outpatient evaluation and management visits. Patients are also assigned based on the recency of outpatient primary care visits or pharmacy claims.	Larson BK, Van Citters AD, Kreindler SA, et al. Insights from transformations under way at four Brookings-Dartmouth accountable care organization pilot sites. Health Aff (Millwood). 2012;31(11):2395-2406. doi:10.1377/hlthaff.2011.1219.
Vermont ACO Pilot	An ACO developed through the collaboration of three health care providers and three commercial insurers in Vermont	Patients are prospectively attributed to an ACO based on their choice of PCP. In cases in which patients are not required to choose a PCP as part of their health insurance, patients are retrospectively attributed based on claims data over a two year period.	Hester J, Lewis J, McKethan A, Fund C. The Vermont Accountable Care Organization Pilot: A Community Health System to Control Total Medical Costs and Improve Population Health.; 2010. Retrieved from http://www.leg.state.vt.us/CommissionOnHealthCareReform/Hester_Vermont_aco_pilot CMWF_final.pdf.
Public Reporting Programs			
California Cooperative Healthcare Reporting Initiative	An initiative to collect and report standardized, reliable health plan and provider performance data in California	CCHRI has tested different methods of assigning patient events to physicians. One approach assigns denominator eligible patients to every physician of a relevant specialty for that measure who had at least one EM visit with the patient during the measurement period (i.e., one-touch rule). By the end of the project, the decision was made to align the numerator and attribution periods so that a physician must have seen the member for an EM visit during the time period in which they were to have received the numerator service.	Delmarva Foundation for Medical Care. Enhancing Physician Quality Performance Measurement and Reporting Through Data Aggregation: The Better Quality Information (BQI) to Improve Care for Medicare Beneficiaries Project. Delmarva Foundation for Medical Care. 2008. Retrieved from http://www.wchq.org/measures/documents/BQI_Final_Report_10_2008.pdf.
California Physician Performance Incentive	A multi-stakeholder initiative to measure and report physician performance in California	A patient is retrospectively attributed to the single PCP with whom the patient had the most ambulatory/outpatient visits during the measurement year and the previous 1 year period. If the number of visits was equal for two or more PCPs, the patient is attributed to the physician that provided care during the most recent visit. For indicators that are relevant to specialists, patients are assigned to any specialist physician whom they saw during the attribution period. Patients can be attributed to more than one specialist for a given indicator. Patients without any visits or without a relevant specialist for a measure are not attributed. Patients are also attributed to "practice sites" (physicians of the same specialty who share the same practice address).	Cromwell J, Trisolini M G, Pope GC, Mitchell, JB, Greenwald LM. Pay for Performance in Health Care: Methods and Approaches. RTI Press Publication. 2011. Retrieved from www.rti.org/rtipress.

Accountability Program	Description	Attribution Method	Related References
Center for Health Information and Research	A regional database in Arizona that documents quality measurements	Patients are attributed to physicians using the following steps: 1. Physical exam or assessment performed by physician with allowed specialty (limited to selected specialties) and who is the PCP assigned via enrollment process. 2. Most recent physical exam or assessment performed by physician other than assigned PCP (limited to allowed specialties) 3. Physician who is in allowed specialty (other than the assigned PCP) and who performed largest number of EM type visits	Delmarva Foundation for Medical Care. Enhancing Physician Quality Performance Measurement and Reporting Through Data Aggregation: The Better Quality Information (BQI) to Improve Care for Medicare Beneficiaries Project. Delmarva Foundation for Medical Care. 2008. Retrieved from http://www.wchq.org/measures/documents/BQI_Final_Report_10_2008.pdf.
Indiana Health Information Exchange	A collaboration of hospitals, providers, researchers, public health organizations, and economic development groups in Indiana to improve health care quality and safety through information technology	In order to attribute the patient to a provider, IHIE created an algorithm that creates a rank ordered list of physician associations with the patient. IHIE then uses data about the providers including their specialty to identify the PCP. The current version of the algorithm relies on actual encounters that occurred (not appointments), laboratory results and prescriptions. Patients fall into one of several categories: A. Patients who have not had interactions with any providers B. Patients who have had interactions with only one provider that meets criteria to be a PCP C. Patients who have had interactions with multiple providers that meet criteria to be PCPs.	Delmarva Foundation for Medical Care. Enhancing Physician Quality Performance Measurement and Reporting Through Data Aggregation: The Better Quality Information (BQI) to Improve Care for Medicare Beneficiaries Project. Delmarva Foundation for Medical Care. 2008. Retrieved from http://www.wchq.org/measures/documents/BQI_Final_Report_10_2008.pdf.
Massachusetts Health Quality Partners	A quality measurement and public reporting program in Massachusetts	Patients in managed care insurance were attributed to the PCP whom the health plan assigned to the patients. For patients in PPO and Medicare FFS products to the PCP who had the highest volume of EM office visits with that patient in the 18 months before the end date of the measurement period. For PPO/FFS patients with no visits to a PCP in the specified measurement period, MHQP attributed care to a visited specialist relevant to the quality indicator (e.g., a cardiologist for cardiac measures).	1. Cromwell J, Trisolini M G, Pope GC, Mitchell, JB, Greenwald LM. Pay for Performance in Health Care: Methods and Approaches. RTI Press Publication. 2011. Retrieved from www.rti.org/rtipress.; 2. Delmarva Foundation for Medical Care. Enhancing Physician Quality Performance Measurement and Reporting Through Data Aggregation: The Better Quality Information (BQI) to Improve Care for Medicare Beneficiaries Project. Delmarva Foundation for Medical Care. 2008. Retrieved from http://www.wchq.org/measures/documents/BQI_Final_Report_10_2008.pdf.

Accountability Program	Description	Attribution Method	Related References
Minnesota Community Measurement	A statewide public quality reporting initiative	Each member in the eligible population for each measure is attributed to one Medical Group for the measurement year based on claims/encounter data for selected services (EM codes and Preventive codes) received in that measurement year. For non-diabetes measures, patients are attributed to group with the highest number of EM claims/encounters if those claims/encounters are associated with the following specialties: general practice, family practice, internal medicine, pediatrics, geriatric medicine, obstetrics and gynecology, cardiology, physician assistant, nurse practitioner. If there is a tie between a primary care and specialist provider, the group with primary care visit is preferred. If there is a tie between 2 PCPs, a patient is attributed to the one with the most recent date of service. Primary Care is defined as general practice, family practice, internal medicine, pediatrics, geriatric medicine, physician assistant, and nurse practitioner. For those members that have claims/encounters that are not associated with one of the specialties listed above, they are assigned to Medical Group 0 (zero). For diabetes measures, members that are not attributed to a medical group using the above steps, they are attributed based on the highest number of EM or diabetes claims/encounters (i.e., maximum frequency rule) during the measurement year regardless of specialty.	Delmarva Foundation for Medical Care. Enhancing Physician Quality Performance Measurement and Reporting Through Data Aggregation: The Better Quality Information (BQI) to Improve Care for Medicare Beneficiaries Project. Delmarva Foundation for Medical Care. 2008. Retrieved from http://www.wchq.org/measures/documents/BQI_Final_Report_10_2008.pdf.

Accountability Program	Description	Attribution Method	Related References
Wisconsin Collaborative for Healthcare Quality	A quality reporting initiative covering over 40 physician groups, hospitals, and health plans in Wisconsin	Members of this initiative self-determine responsibility for their patients based on three questions: For disease-specific measures: 1) Is this a patient with the disease or condition? – Patients require a defined number of office visits for their condition to qualify for the measure. 2) Is this patient whose care is managed within the physician group? Patients are required to be managed by the physician group in order to be eligible for the measure. 3) Is this a patient currently managed in our system – Patients must be currently managed by the physician group in order to be included in the measure. For other measures: 1) Is this a patient we manage? - Patients are required to be managed by the physician group in order to be eligible for the measure. 2) Is this a patient that is current in our system? Patients must be currently managed by the physician group in order to be included in the measure. 3) Is this a patient that is eligible for the measure? – Patients who meet the defined measure eligibility criteria	1. Delmarva Foundation for Medical Care. Enhancing Physician Quality Performance Measurement and Reporting Through Data Aggregation: The Better Quality Information (BQI) to Improve Care for Medicare Beneficiaries Project. Delmarva Foundation for Medical Care. 2008. Retrieved from http://www.wchq.org/measures/documents/BQI_Final_Report_10_2008.pdf.; 2. Greer A. Embracing Accountability: Physician Leadership, Public Reporting, and Teamwork in the Wisconsin Collaborative for Healthcare Quality. The Commonwealth Fund. 2008. Retrieved from http://www.commonwealthfund.org/~/media/files/publications/fund report/2008/jun/embracing accountability physician leadership public reporting and teamwork in the wisconsin coll/greer_embracingaccountabilitywisconsincollab_1142 pdf.pdf.

Value-based Purchasing/ Pay-for-Performance

Accountability Program	Description	Attribution Method	Related References
Medicare Physician Group Practice Demonstration Project	A 5-year P4P initiative that incentivized physician group to coordinate the care they provided to Medicare beneficiaries	Beneficiaries were retrospectively assigned to the practice group that provided the plurality of office or other outpatient evaluation and management services during the performance year.	1. Centers for Medicare & Medicaid Services. PGP fact sheet. CMS. 2009. Retrieved from http://www. cms.gov/Medicare/Demonstration-Projects/DemoProjectsEvalRpts/downloads//PGP_ Fact_Sheet.pdf ; 2. Kautter J, Pope GC, Trisolini M, Grund S. Medicare Physician Group Practice Demonstration design: Quality and efficiency pay-for- performance. Health Care Financing Review. 2007; 29(1): 15−29.; 3. Pope GC, Trisolini M, Kautter J, Ada- manche W. Physician Group Practice (PGP) demonstration design report. CMS. 2002.; 4. Cromwell J, Trisolini M G, Pope GC, Mitchell, JB, Greenwald LM. Pay for Performance in Health Care: Methods and Approaches. RTI Press Publication. 2011. Retrieved from www.rti.org/rtipress.; 4. McKethan A. Improving Quality and Value in the US: Health Care System. Bipartisan Policy Center. 2009. Retreived from: http://bipartisanpolicy.org/wp-content/uploads/sites/default/files/BPC8-09-PCHC%20Qual%20rpt-8-20-09.pdf; 5. Schneider E, Hussey PS, Schnyer C. Payment Reform. RAND Health. 2011. Retrieved from http://s3.amazonaws.com/rdcms-himss/files/production/public/HIMSSorg/Content/files/RANDReportMeasurementImplicationsPerformance-BasedPaymentReformModels.pdf.; 5. Kautter J, Pope G, Leung M, Trisolini M, Adamache W, Smith K. Financial and quality impacts of the medicare physician group practice demonstration. Medicare Medicaid Res. Rev. 2014; 4(3):E1–22.
Physician Value-Based Payment Modifier	This program began in 2015 and offers differential payments to physicians and physician groups on the basis of the quality and value of care provided to attributed beneficiaries during a performance period	Beneficiaries are retrospectively attributed to the group that provides the plurality of primary care services. Primary care services include office-based, home health, or nursing home evaluation and management codes as well as other codes defined by CMS. Certain large single specialty groups – such as those limited to emergency medicine, diagnostic radiology, pathology, and anesthesiology – may not be attributed any beneficiaries under this attribution methodology	Centers for Medicare & Medicaid Services. Summary of 2015 Physician Value-based Payment Modifier Policies. CMS. 2013. Retrieved from http://www.cms.gov/ Medicare/Medicare-Fee-for-Service-Payment/PhysicianFeedbackProgram/Downloads/ CY2015ValueModifierPolicies.pdf

Physician Profiling and Network Tiering

Accountability Program	Description	Attribution Method	Related References
Aetna	This approach relates to Aetna's method for attributing patients for purposes such as network tiering, providing physicians with feedback report, and public reporting	Episodes are assigned to physician with majority of claims dollars included in the episode, or to surgeon if a surgery occurs.	Lake T, Colby M, Peterson S. Health Plans' Use of Physician Resource Use and Quality Measures. Mathematica Policy Research. 2007. Retrieved from https://www.mathematica-mpr.com/our-publications-and-findings/publications/health-plans-use-of-physician-resource-use-and-quality-measures.
		Episodes are assigned to each physician with more than 20% of claims dollars included in the episode.	

Accountability Program	Description	Attribution Method	Related References
Blue Cross/Blue Shield	This approach relates to Blue Cross/Blue Shield's method for attributing patients for purposes such as network tiering, providing physicians with feedback report, and public reporting	Episode assigned to physician who bills the greatest total Relative Value Units (RVUs) for a given episode, as long as the physician has a minimum number of RVUs. When no physician is identified by RVUs, episode is attributed to the physician billing the greatest number of outpatient evaluation or management services for the episode, as long as the physician has a minimum number of outpatient EM services. When no physician is identified by either of the above, episode is attributed to the physician with the highest allowable cost included in the episode.	Lake T, Colby M, Peterson S. Health Plans' Use of Physician Resource Use and Quality Measures. Mathematica Policy Research. 2007. Retrieved from https://www.mathematica-mpr.com/our-publications-and-findings/publications/health-plans-use-of-physician-resource-use-and-quality-measures.
Clinical Performance Improvement (CPI) Initiative	An initiative In Massachusetts that involves the construction a consolidated, multi-plan claims database to develop cost-efficiency and quality of care profiles for physicians that can be used by health plans to partition their physician networks into preferred and non-preferred tiers.	Episode responsibility is attributed to the physician accounting for the highest portion of professional cost in the episode, so long as the physician's portion equals at least 25%. Ideally, episode responsibility should reflect all costs – professional, inpatient, outpatient, and pharmacy	Green RA, Beckman HB, Patridge GH, Thomas JW. Review of the Massachusetts Group Insurance Commission Physician Profiling and Network Tiering Plan: a report to the Massachusetts Medical Society. Massachusetts Medical Society. 2006. Retrieved from http://www.massmed.org/AM/Template.cfm?Section=Pay_for_Performance&TEMPLATE=/CM/ContentDisplay.cfm&CONTENTID=16760; See also: Alteras T, Silow-Carroll S. Value-driven health care purchasing: a case study of the Massachusetts group insurance commission. The Commonwealth Fund. 2007. Retrieved from http://www.commonwealthfund.org/usr_doc/1053_Alteras_value-driven_Massachusetts_case_study.pdf.
Harvard Pilgrim Health Care	This approach relates to Harvard Pilgrim Health Care's method for attributing patients for purposes such as network tiering, providing physicians with feedback report, and public reporting	Episodes are assigned to physician with the highest amount of claims dollars, as long as physician is responsible for at least 25% of the episode fees charged. If no physician has at least 25% of the claims dollars for the episode, the episode remains unassigned.	Lake T, Colby M, Peterson S. Health Plans' Use of Physician Resource Use and Quality Measures. Mathematica Policy Research. 2007. Retrieved from https://www.mathematica-mpr.com/our-publications-and-findings/publications/health-plans-use-of-physician-resource-use-and-quality-measures.
United HealthCare	This approach relates to United Health Care's method for attributing patients for purposes such as network tiering, providing physicians with feedback report, and public reporting	For non-proceduralists, episodes are assigned to the physician with the majority of claims dollars included in the episode .For proceduralists, episodes are assigned to physician who submitted the claim for the interventional procedure.	Lake T, Colby M, Peterson S. Health Plans' Use of Physician Resource Use and Quality Measures. Mathematica Policy Research. 2007. Retrieved from https://www.mathematica-mpr.com/our-publications-and-findings/publications/health-plans-use-of-physician-resource-use-and-quality-measures.
Patient-Centered Medical Home			
Medical Services Initiative	A patient-centered medical home initiative for low-income, uninsured patients in Orange County, California	Patients are prospectively attributed to a medical home (clinic or private physician) at the time of enrollment based on choice or assignment. Within clinic-based medical homes, the enrollee chooses or is assigned to a specific physician to serve as their personal provider. This decision may be based on personal relationships, recommendation, language spoken by the provider, or proximity to the enrollee's home. This medical home is intended as the source for all primary care.	Roby DH, Pourat N, Pirritano MJ, Vrungos SM, Dajee H, et al. Impact of patient-centered medical home assignment on emergency room visits among uninsured patients in a county health system. Med. Care Res. Rev. 2010; 67(4):412–30.
Minnesota's Health Care Home Initiative	An statewide initiative in Minnesota to incentivize PCPs to provide comprehensive care to their members through a medical home model	PCPs are assigned clinics using an algorithm that considers the Statewide Quality Reporting and Measurement system registry. Patients are then retrospectively attributed to clinics based on an algorithm that considers: 1. the clinic that associated with the provider in which they had the greatest number of EM encounters; 2.the number of clinic encounters that are with an MD/DO, NP, or PA; 3. date of most recent visit to clinic. In order to make an attribution, at least 10% of an enrollee's professional service encounters must be with the clinic.	Wholey D, Finch M, Shippee ND, et al. Evaluation of the State of Minnesota's Health Care Home Initiative: Evaluation Report for years 2010-2012. Minnesota Department of Health. 2014. Retrieved from http://www.health.umn.edu/sites/default/files/UM 2015 HCH Evaluation Final 07Feb2016.pdf.

Table 5. Summary of attribution approaches from proposed models identified in the literature search

Citation	Description	Attribution Method
Attribution of Episodes of Care		
Adams JL, McGlynn EA, Thomas JW, Mehrotra A. Incorporating Statistical Uncertainty in the Use of Physician Cost Profiles. BMC Health Serv Res. 2010; 10:57.	This study utilizes data from four commercial insurers in Massachusetts to analyze methods to develop physician cost profiles for the purpose of public reporting and quality improvement.	Using claims data, each episode of care was retrospectively attributed to the physician who had billed the greatest fraction (at least 30%) of the professional costs related to the episode. Physicians were then categorized as low cost, average cost, or high cost.
Halpern R, Kothari S, Fuldeore M. GERD-related health care utilization, therapy, and reasons for transfer of GERD patients between primary care providers and gastroenterologists in a US managed. Dig Dis Sci. 2010; 55(2):328-337.	This article analyzes health care utilization among patients with gastroesophageal reflux disease treated by PCPs and gastroenterologists.	Episodes were categorized as PCP if at least 55% of GERD-related utilization, including office visits, procedures, and GERD medication fills, was associated with a PCP physician (general practitioner, family practitioner or internal medicine). Episodes were classified as GE if at least 55% of GERD-related utilization was associated with a GE specialty code. All remaining episodes were classified as "other;" these episodes were characterized by specialty codes associated with ear, nose, and throat, emergency medicine, general surgery, and facilities
Huckfeldt P, Chan C, Hirshman S, Kofner A. Specialty Payment Model Opportunities and Assessment. CMS Alliance to Modernize Healthcare. 2015. Retrived from http://www.rand.org/content/dam/rand/pubs/research_reports/RR700/RR763/RAND_RR763.pdf.	This report examines the use episode-based payment models for oncology care.	Patient episodes were attributed to practices using two strategies: 1. Retrospective attribution based on the plurality of cancer-related visits for EM services over a 60 day period that was preceded by a 30 day period in which no cancer-related claims were reported. In cases of ties, the measurement period was extended for an additional 90 day period.
		2. Prospective attribution to the practice responsible for the trigger chemotherapy claim (i.e., the claim that is used to identify the initiation of the chemotherapy treatment episode). Attribution using an EM claim on the same day as trigger event was prioritized followed by the practice billing the greatest number of EM visits on the same day as a claim for a chemotherapy drug. The measurement period window was extended in the case of ties. Episodes were attributed to physicians in the hospital outpatient department if no other attribution could be made.
Ingenix. Symmetry episode treatment groups: Issues and best practices in physician episode attribution. 2007. Retrieved from https://etg.optum.com/Ingenix/Media/ETG/Symmetry_EpisodeAttribution_WP_FINAL_112007_L01.pdf.	This white paper examines different approaches and identifies best practices for attributing episodes to providers	This paper evaluates the following attribution approaches: 1. Physician Episode Attribution Using Professional Service Costs: This attribution approach identifies the responsible physician for an episode as that provider rendering the greatest amount of professional service costs during the episode
		2. Physician Episode Attribution Using Episode Clusters: This attribution approach identifies the responsible physician for an episode as that provider in the peer group owning the greatest number of "clusters" within the episode.
		3. Physician Episode Attribution Using Non-Acute EM Visits: This attribution approach identifies the responsible physician for an episode as that physician providing the greatest number of non-acute EM visits within the episode.
		4. Physician Episode Attribution Using a Primary Care, Population-based Approach: Responsibility for a member's qualified episodes of care may be attributed to the member's PCP—whether or not the PCP provided any of the services for that member during those episodes.
MaCurdy T, Theobald N, Kerwin J, Ueda K. Prototype Medicare Resource Utilization Report Based on Episode Groupers. Acumen, LLC. 2008. Retrieved from https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/Reports/downloads/MaCurdy2.pdf.	This report provides recommendations to CMS on the attribution of episodes to providers for the purpose of examining physician resource utilization	This paper evaluates the following attribution approaches: 1. Beneficiaries are attributed to the provider associated with the greatest number of Part B costs. If there are no positive costs on Part B claims assigned to an episode, then the episode is not attributed to a provider. In the case where the payments from Part B claims to two or more providers are equal, then the next rule applied breaks the tie between the providers by attributing the episode the provider with the highest costs from EM claims
		2. Beneficiaries are attributed to the provider with the most EM charges. When there is a tie in EM costs among providers, it is broken by attributing the episode to the provider with the highest Part B costs. If both EM and Part B costs are tied among providers, then the algorithm moves to numbers of EM claims followed by numbers of Part B claims.
MedPAC. Using episode groupers to assess physician resource use. Report to the Congress: Increasing the Value of Medicare. 2006. Retrieved from http://www.medpac.gov/documents/reports/Jun06_EntireReport.pdf?sfvrsn=0.	This report discusses different approaches for attributing episode to providers to assess physician resource use	This report examines the following approaches: Percentage of Evaluation and Management Visits, single provider: 1. 30%
		2. 35%
		3. 40%
		4. 50%
		Percentage of non-inpatient EM visits, single provider: 5. 30%
		Percentage of EM dollars, single provider: 6. 30%
		7. 35%
		8. 40%
		9. 50%
		Multiple provider, attribution by visits: 10. 35%

Citation	Description	Attribution Method
Mehrotra A, Adams J, Thomas J, McGlynn E. Cost profiles: should the focus be on individual physicians or physician groups? Health Aff (Millwood). 2010; 29(8):1532-8.	This article assesses approaches for developing physician cost profiles.	Beneficiaries receiving at least one primary care service from a PCP (defined by specialty codes for general practice, family practice, internal medicine, or geriatric medicine) were retrospectively assigned based on primary care services provided by PCPs. Beneficiaries with multiple primary care services were assigned to the ACO in which they had the greatest outpatient spending. Beneficiaries receiving no primary care services from a PCP were assigned based on primary care services provided by physicians of other specialties, nurse practitioners, or physician assistants. Beneficiaries receiving no primary care services were not assigned.
Mehrotra A, Liu H, Adams J. The costs and quality of care for three common illnesses at retail clinics as compared to other medical settings. Ann Intern Med. 2009; 151(5): 321-328.	This article examines the quality of care at retail clinics compared to other health facilities.	The total cost of an episode of care was attributed to the physician who accounted for the highest fraction (minimum 30%) of professional costs within the episode. If the physician worked in a group, the episodes assigned to a physician were also assigned to this group.
Metfessel B, Greene R. A nonparametric statistical method that improves physician cost of care analysis. Health Serv Res. 2012; 47(6): 2398-417.	This article analyzes methods to develop physician cost profiles using episode treatment groups.	Episodes were retrospectively attributed to provider facilities according to the location of the first EM visit in the episode: retail clinic, physician office, urgent care clinic, or emergency department.
Nyman M. Inclusion of short-term care patients affects the perceived performance of specialists: a retrospective cohort study. BMC Health Serv Res. 2015; 15:99.	This articles looks at how difference in quality measurement period length impact quality performance profiles for specialists.	Each episode was attributed to the single physician who generated the highest percentage of costs in an episode. Only episodes in which a physician was responsible for at least 30% of costs were attributed.
Sandy LG, Rattray MC, Thomas JW. Episode-based physician profiling: a guide to the perplexing. J Gen Intern Med. 2008; 23 (9): 1521-1524. 10.1007/s11606-008-0684-z.	This articles discusses the strengths and limitations of episode-based provider profiling.	This paper evaluates the following attribution approaches: 1. Episodes were assigned to the physician who accounted for 30% or more of professional and prescribing costs included in the episode.
		2. Episodes were attributed to a physician in a relevant specialty (e.g., internal medicine, endocrinology) who had the largest number of EM encounters during the profiling period.
National Quality Forum. National Voluntaty Consensus Standards for Cost and Resource Use. 2012. Retrieved from www.qualityforum.org/Publications/.../Cost_and_Resource_Use_Final_Report.aspx	This report provides recommendations on combining resource use data and quality to promote efficiency in health care.	This report outlines several attribution approaches that can be applied to 1. Physician Episode Attribution using Professional Service Costs. This attribution approach identifies the responsible physician for an episode as that provider rendering the greatest amount of professional service costs during the episode.
		2. Physician Episode Attribution using Episode Clusters. This attribution approach identifies the responsible physician for an episode as that provider in the peer group owning the greatest number of "clusters" within the episode.
		3. Physician Episode Attribution using Non-Acute EM Visits. This attribution approach identifies the responsible physician for an episode as that physician providing the greatest number of non-acute EM visits within the episode.
		4. Physician Episode Attribution using a Primary Care, Population-based Approach. This approach requires two important steps: 1) Identification of a PCP for each member. 2) Identify the patient's assigned PCP during the episode period.
Thomas JW, Ward K. Economic profiling of physician specialists: use of outlier treatment and episode attribution rules. Inquiry. 2006;43(3):271–282.	This article analyzes methods to attribute patients to physician in order to develop economic profiles.	Episodes were retrospectively assigned to one or more physicians using one of the following approaches:1. 20% rule- 20% or more of professional and prescribing costs for an episode
		2. 30% rule- 30% or more of professional and prescribing costs for an episode
		3. 50% rule- 50% or more of professional and prescribing costs for an episode.
Timbie J, Hussey P, Adams J. Impact of socioeconomic adjustment on physicians' relative cost of care. Med Care. 2013; 51(5): 454-60.	This study examines the impact of socioeconomic status adjustment on episode-based physician cost profiling.	Episodes of care and their associated costs were retrospectively attributed to the physician having a plurality of professional costs (subject to a minimum of 30 percent of total professional costs) within the episode.

Citation	Description	Attribution Method
Attributing Patients to Hospitals, Physician Networks, or ACOs		
Anderson L, Flottemesch T. Patient medical group continuity and healthcare utilization. Am J Manag Care. 2012; 18(8): 450-7.	This article analyzes the continuity of care over a 5 year period among patients insured by HealthPartners.	Patients were retrospectively attributed using claims data to the medical group where they had the greatest number of primary care visits. In case of ties, patients were attributed to the medical group where the most recent visit occurred. Primary care visits were defined by location and specialty of the billing physician and included the following specialties: family medicine, internal medicine, pediatrics, geriatrics, and obstetrics and gynecology. Nurse practitioner and physician assistant visits were also included. Patients without primary care visits in a year were not attributed in that year.
Bynum JPW, Bernal-Delgado E, Gottlieb DJ, Fisher ES. Assigning ambulatory patients and their physicians to hospitals: a method for obtaining population-based provider performance measurements. Health Serv Res. 2007;42(1):45–62.	This study analyzes the validity of using claims data to assign Medicare FFS beneficiaries to physicians and hospitals for the purpose of developing population-based estimates of provider costs and quality.	Patients were retrospectively assigned to their predominant ambulatory physician. This was defined as the generalist (internist, geriatrician, family, or general practitioner) or specialist with whom the patient had the most ambulatory visits during the 2 years after an index visit to any provider in 1998. If there were no visits to generalists or specialists, patients were assigned to other physician types (e.g., dermatologists or surgeons). If the number of visits to physicians of equal priority was tied, the physician with the greatest time span between the first and last visits was chosen to favor longitudinal patient–physician relationships. If a patient had only one visit to each, then the most recent was chosen.
Everett C, Thorpe C. Division of primary care services between physicians, physician assistants, and nurse practitioners for older patients with diabetes. Med Care Res Rev. 2013; 70(5):531-41.	This study analyzes the division of services between PCPs for Medicare patients with diabetes.	Patients were first assigned to the primary care clinic that provided the majority of their face-to-face visits, then to the provider (physician or PA/NP) that delivered the majority of visits within that clinic. In the event of a tie, patients were assigned to the clinic/provider with the most recent visit. Patient panels grouped patients assigned to the same usual provider of care within a clinic.
Fisher ES, Staiger DO, Bynum JPW, Gottlieb DJ. Creating accountable care organizations: the extended hospital medical staff. Health Aff (Millwood) 2007;26(1):w44–57. DOI: 10.1377/hlthaff.26.1.w44.	This study analyzes whether it is feasible to use hospitals and their extended medical staff as the locus of performance assessment and accountability	Patients and physicians were assigned to hospitals using a three-year period of claims data. 60% of physicians were assigned to the hospital where they provided care to the greatest number of inpatients. Physicians who did not treat inpatients were assigned to hospitals according to where the plurality of their patients were admitted. Patients were assigned to the physicians who provided the most ambulatory care. Patients were then assigned to hospitals on the basis of their physicians' designation. Secondary hospitals were defined as the single other hospital most frequently used by a primary hospital's ambulatory cohort.
Hirth R, Turenne M. Provider Monitoring and Pay-for-Performance When Multiple Providers Affect Outcomes: An Application to Renal Dialysis. Heal Serv Res. 2009; 44(5.1): 1585-602.	This study analyzes the affect of dialysis facilities and nephrologists resource use on patient outcomes.	Patients were retrospectively attributed to providers and facilities using the unique physician identification number code reported on dialysis claims. Patients could be attributed to more than physician and/or facility.
Lewis VA, McClurg AB, Smith J, Fisher ES, Bynum JP. Attributing patients to accountable care organizations: performance year approach aligns stakeholders' interests. Health Aff (Millwood). 2013;32(3):587-95.	This study evaluates approaches for defining the patient population of Medicare ACOs by simulating the formation of ACOs based on Medicare FFS claims data.	The study compared the following two approaches: Prospective- Patients' use of service in the previous year was used to prospectively assign patient to providers during the performance year
		Performance Year- Patients were retrospectively attributed to providers on the basis of their service utilization during the performance year period The study also varied inclusion specifications such as only attributing patients to PCPs.
		Patients were then assigned to the hospital where their physician provided inpatient services or where a plurality of that physician's patient panel had medical admissions.
McWilliams J. Outpatient care patterns and organizational accountability in Medicare. JAMA Intern Med. 2014; 174(6): 938-45.	This article uses Medicare claims data to assess the capacity of hypothetical ACOs.	Beneficiaries were attributed to the ACO that provided the accounted for the greatest proportion of outpatient primary care spending.
Pollack C, Bekelman J, Liao K, Armstrong K. Hospital racial composition and the treatment of localized prostate cancer. Cancer. 2011; 117(24): 5569-78.	This study investigates racial differences in the treatment of men with prostrate cancer.	1. Patients were attributed to the hospital from which they had the most distinct visits
		2. Patients were also attributed to the first hospital where they were seen either on their date of diagnosis or the first hospital in which they were seen after the date of diagnosis

Citation	Description	Attribution Method
Pollack C, Weissman G. Physician social networks and variation in prostate cancer treatment in three cities. Heal Serv Res. 2012; 47(1.2): 380-403.	This study analyzes physician networks and whether they are associated with variations in prostate cancer treatment.	In order to construct physician networks, patients were attributed to several providers:1. Diagnosing urologist. The urologist who billed for a claim on the date of the patient's diagnosis. If no claim was submitted, the patient was attributed to the urologist who saw the patient nearest to the date of diagnosis in the 3 months prior. If no urologist was identified, attribution was made to the urologist who saw the patient nearest to the date of diagnosis in the 3 months following diagnosis.
		2. Majority urologist was defined as the urologist who billed for claims on the most days in the 9 months following diagnosis.
		3. PCP was defined as the internal medicine (without subspecialty training), family practice, or general practice physician who billed for the greatest number of visits.
		4. Plurality provide- Patients were attributed to doctors who billed for the greatest numbers of EM visits in the 12 months prior to the date of diagnosis, regardless of their clinical specialty.
		5. Radiation oncologists. For patients who underwent external beam radiation and brachytherapy, attribution was also made to the provider who performed the clinical planning and simulation.
Attribution Using Statistical Modeling		
Atlas SJ, Chang Y, Lasko TA, Chueh HC, Grant RW, Barry MJ. Is This "My" Patient? Development and Validation of a Predictive Model to Link Patients to Primary Care Providers. Journal of General Internal Medicine. 2006;21(9):973-978. doi:10.1111/j.1525-1497.2006.00509.x.	In this study, 18 PCPs from MGHN reviewed patient records and designated each patient as "My Patient" or "Not My Patient" in order to develop and validate an approach to link patients to PCPs.	PCPs retrospectively attributed patients to their patient panel by reviewing all records for outpatient visits over a 3 year period. This information was then used to develop an algorithm with logistic regression modeling to attribute patients to providers. The model contained the following variables: PCP designee in registration field, physician practice style, patient age, months since last visit with physician, and patient's residence listed as in state.
Atlas S, Grant R, Ferris T. Patient–physician connectedness and quality of primary care. Ann Intern Med. 2009; 150(5): 325-35.	This article analyzes whether patient connectedness influences measures of physician performance.	The following steps were used to attribute patients to providers: 1. Patient registered with a MGH PCP, 2. Patient had at least one visit to PCP, 3. Patients connected through algorithm. In cases, where a patients was registered with and visited a resident, patients were attributed to a practice group.
Lasko TA, Atlas SJ, Barry MJ, Chueh HC. Automated identification of a physician's primary patients. J Am Med Inform Assoc. 2006;13:74–9.	In this study, 18 PCPs from MGHN reviewed patient records and designated each patient as "My Patient" or "Not My Patient" in order to develop and validate an approach to link patients to PCPs.	PCPs retrospectively attributed patients to their patient panel by reviewing all records for outpatient visits over a 3 year period. This information was then used to develop an algorithm with logistic regression modeling to attribute patients to providers. The model contained the following variables: waiting fraction, visit difference, days since last visit, idle ratio, practice style, and future difference.
Attribution in International Contexts		
Kang HC, Hong JS. Do differences in profiling criteria bias performance measurements? Economic profiling of medical clinics under the Korea National Health Insurance program: An observational study using claims data. BMC Health Serv Res. 2011; 11: 189.	This study analyzes how differences in two case-mix classification systems influence the calculation of cost-efficiency indexes for outpatient clinics in South Korea	1. Korean Classification of Diseases- All cases were attributed to clinics. Patients were classified using a 3 digit disease code and subdivided into surgical and non-surgical groups.
		2. Korean Outpatient Group- Only cases with one of the 300 most frequent disease groups are attributed to clinics.
Lavergne M. Understanding geographic variation in health care costs in British Columbia. 201. Dissertation, University of British Columbia. Retrieved from https://circle.ubc.ca/handle/2429/52302.	This study examines variations in care through an analysis of multispecialty physician networks in British Columbia, Canada.	For this analysis, patients were assigned to the individual PCP responsible for the plurality of their primary care over the study period. This was measured by fee-adjusted dollars billed within general practice service codes, summed over the study period. In the case of a tie, the patients were assigned to the primary care provider with the most recent visit. Any remaining unlinked residents were assigned to the physician (primary care or specialist) who provided the highest total volume of ambulatory physician services. This was measured by dollars billed for visits, laboratory tests, and diagnostic tests provided in locations other than emergency departments, inpatient hospital or day surgery. Services provided in outpatient and/or ambulatory clinics located in hospitals were included. Residents who had no ambulatory contact with a physician were not linked to a usual provider of primary care, but could be linked to a network if they had hospital service use.
Roos NP. Linking Patients to Hospitals: Defining Urban Hospital Service Populations. Medical Care. 1993; 31(5): YS6–15.	This articles analyzes variations in the delivery of health services by defining urban hospital service areas.	Patients were retrospectively attributed to the physician (PCP or specialist) with whom they had the greatest number of ambulatory, out-of-hospital contacts in 1983. Patients were then linked to the hospital where they were seen most frequently by their assigned physician. If they had no hospital visits, then they were attributed to hospital based on where their physician most frequently contacted other patients. When patients could be linked to two or more hospitals, the patient was attributed to the hospital where their assigned physician practiced most often
		Other attribution approaches were also tested including: assigning patients to hospitals based on the plurality of the physicians contacted

Citation	Description	Attribution Method
Stukel T, Glazier R, Schultz S. Multispecialty physician networks in Ontario. Open Med. 2013; 7(2):e40-e55.	This study analyzes multispecialty physician networks to understand how naturally occurring relationships among physicians can be leveraged to foster accountability.	A patient was attributed to the PCP (general practitioner, family practitioner, or pediatrician) with whom he or she had been rostered at the midpoint of the study period. If a patient was not on a roster, he or she was linked to the PCP who provided the greatest amount of primary care services according to billing codes. Remaining unattributed residents were linked to any provider (PCP prioritized) who billed for the greatest number of ambulatory services. Residents without any ambulatory services were not attributed to a physician. Residents were then linked to the hospital where their physician was assigned. Unlinked patients were directly attributed to a hospital if they were admitted or visited an ED.
Provost S, Pérez J. An algorithm using administrative data to identify patient attachment to a family physician. Int J Fam Med. 2015; 2015.	The study analyzes an algorithm for attributing to patients to family practitioners using administrative data.	Attribution of patients to providers were done based on an algorithm that first considered a patient's enrollment status to the family group provider. In cases in which patients were not enrolled, patients were attributed to the provider the patient saw for a complete medical examination conducted during a two-year period. If an attribution could still not be made, patients were assigned based on concentration of visits to the same provider over time.
Analyses of Multiple Attribution Approaches		
Damberg C, Sorbero M, Hussey PS, Lovejoy S, Liu H, Mehrotra A. Exploring Episode-Based Approached for Medicare Performance Measurement, Accountability, and Payment. Office of the Assistant Secretary of Planning and Evaluation. 2009. Retrieved from http://aspe.hhs.gov/health/reports/09/mcperform/report.pdf.	This report assesses various episode-based attribution approaches as they related to performance measurement, accountability, and payment in Medicare.	This report analyzed the following attribution approaches: 1. Episode EM visit plurality, at least 30%
		2. Episode professional payment plurality, at least 30%, single physician
		3. Episode professional payment, multiple physician, at least 25%
		4. Facility payment plurality, single facility, at least 30%
		5. Facility payment, multiple facility, at least 25%
		6. Episode professional payment plurality and facility payment plurality, at least 30% for each
Delmarva Foundation for Medical Care. Enhancing Physician Quality Performance Measurement and Reporting Through Data Aggregation: The Better Quality Information (BQI) to Improve Care for Medicare Beneficiaries Project. Delmarva Foundation for Medical Care. 2008. Retrieved from http://www.wchq.org/measures/documents/BQI_Final_Report_10_2008.pdf.	This report analyzes the validity and reliability of various attribution approaches for Medicare FFS beneficiaries using claims data.	Patients were retrospectively attributed to physicians using one of the following strategies: A) Potential for Multiple Physicians per Patient 1. One-touch rule- patient is attributed to every physician with whom he/she had at least one EM visit
		2. Two-touch rule- patient is attributed to every physician with whom he/she had at least two EM visits
		3. 30% rule- patient is attributed to every physician who submitted at least 30% of total office visits
		B) One Physician per patient: 1. 50% rule- patient is attributed to the physician who submitted at least 50% of total office visits. If two physicians each have, then the patient is randomly assigned to one physician.
		2. Maximum frequency- patient is assigned to the physician with the highest claims based on EM visits. In the case of a tie, a patient is assigned to the physician seen during the most recent visit.
Dowd B, Li C, Swenson T, Coulam R, Levy J. Medicare's Physician Quality Reporting System (PQRS): quality measurement and beneficiary attribution. Medicare & medicaid research review. 2014; 4(2).	This study evaluates the use of the PQRS reporting system to supplement existing attribution algorithms.	Patients were retrospectively attributed to providers using the following approaches: 1. Patients were attributed to the provider who accounted for the plurality of a patient's non-hospital EM visit
		2. Patients were attributed to a provider who reported a measure through the Physician Quality Reporting System
HealthPartners. Assigning Accountability to Health Care Costs: An Observational Study of Assigning Health Care Accountability. 2016. Retrieved from https://www.healthpartners.com/ucm/groups/public/@hp/@public/documents/documents/cntrb_031064.pdf	Health Partners is an integrated health care provider and insurance company based in Minnesota. This study involved the analysis of the primary care commercial claims for approximately 800,000 HealthPartners members in order to evaluate attribution approaches.	The following retrospective attribution approaches were analyzed using claims data: 1. Most Visits: All Settings – The highest percentage of primary care visits in all care settings
		2. Most Visits: Office or Outpatient – The highest percentage of primary care visits in office and outpatient settings.
		3. Most EM Visits – The highest percentage of primary care EM visits.
		3a. Most Visits: Expanded EM – The highest percentage of expanded primary care EM visits.
		4. Majority of EM Visits – Greater than 50% of primary care EM visits.
		5. Majority of Dollars: All Settings – Greater than 50% of primary care dollars.

Citation	Description	Attribution Method
Hussey P, Sorbero M, Mehrotra A. Using Episodes of Care as a Basis for Performance Measurement and Payment: Moving from Concept to Practice. Heal Aff (Project Hope). 2009; 28(5): 1406-17.	This article identifies key issues related to defining episodes and determining which provider is accountable for an episode	The following attribution approaches were evaluated: 1. The physician with the highest percentage of professional payments, over a minimum of 30%
		2. Any physician with at least 25% of professional payments
		3. The physician with the highest number of EM visits, over a minimum of 30%
		4. The facility with the highest percentage of facility payments, over a minimum of 30%
		5. All facilities with at least 25% of facility payments
		6. The facility with the highest percentage of facility payments and the physician with the highest percentage of professional payments, each over a minimum of 30%
Leapfrog Group, Bridges to Excellence. Measuring Provider Efficiency, Version 1.0. 2004. Retrieved from http://www.commonwealthfund.org/publications/ other/2004/dec/measuring-provider-efficiency--version- 1-0--a-collaborative-multi-stakeholder-effort.	This white paper provides an overview of best practices to improve the measurement or provider efficiency. As part of the recommendations, the pros and cons of several general attribution strategies are described.	1. Highest Cost Clinician- Of the clinician fees within each episode's total claims activity, the clinician with the highest percentage of expenses is assigned responsibility for the total episode.
		2. Clinician's Expense Percentage Threshold Episode -Responsibility is determined based on an established threshold percentage of total eligible clinician fees.
		2a. Single Clinician with Greatest Share of Professional Costs, with Threshold: responsibility is assigned to physician with the greatest share of eligible fees, but must also be greater than a threshold level
		3. PCP and Specialist Assignment For HMO and POS: episode assignment is based on either method one or two above, but the episodes would also be assigned to the member's PCP, regardless of whether the PCP had any claims activity within the episode.
		4. Virtual PCPs/Specialists: For non-gate keeper models, the assignment is made to a PCP who is involved in an episode, regardless of the percentage of clinician fees, or based on the overall historical claims history
		5. Assignment to All Involved Clinicians: For every provider involved in every episode, the provider is assigned responsibility for each episode.
		6. Major Procedure Provider: For cases where a "significant" procedure occurs within the case, the provider that renders the service is assigned responsibility for the episode, regardless of the level of involvement of other clinicians.
		7. Most Face-to-Face Encounters
Mehrotra A, Adams JL, Thomas JW, McGlynn EA. The effect of different attribution rules on individual physician cost profiles. Ann Intern Med. 2010;152(10):649–54.	This study analyzes 12 different attribution approaches for determining physician cost profiles.	In this analysis, attributions were made retrospectively, but varied on the basis of the components: a. Unit of analysis: Episode- costs are assigned separately for each condition, Patient- all costs for a patient are assigned to one or more physicians; b. Signal of responsibility: Cost- professional costs; Visits- EM visits; c. Number of physicians: Single, Multiple, d. Threshold: Majority- 50% or more, Plurality- 30% or more; Varying the components above, the researchers analyzed the following attribution approaches:1. Episode, cost, plurality
		2. Episode, cost, majority
		3. Episode, visit, plurality
		4. Episode, visit, majority
		5. Patient, cost, plurality
		6. Patient, cost, majority
		7. Patient, visit, plurality
		8. Patient, visit, majority
		9. Episode, cost, multiple-physician
		10. Episode, visit, multiple-physician
		11. Patient, cost, multiple-physician
		12. Patient, visit, multiple-physician
Pham H, O'Malley A. Primary care physicians' links to other physicians through Medicare patients: the scope of care coordination. Ann Intern Med. 2009; 150(4): 236-42.	This study analyzes the number of physicians providing primary care to Medicare patients.	Patients were attributed using the following strategies: 1. PCP that billed the greatest number of EM visits (Plurality assignment)
		2. PCP that billed for at least 50% of EM visits in the year 2005. Ties were resolved in both strategies by assignment to the physician who billed for the greatest total charges for that beneficiary.

Citation	Description	Attribution Method
Pham HH, Schrag D, O'Malley AS, Wu B, Bach PB. Care patterns in Medicare and their implications for pay for performance. N Engl J Med. 2007;356(11):1130-1139. doi:10.1056/NEJMsa063979.	Medicare Claims This study is an analysis of Medicare claims data for FFS beneficiaries that were treated by physicians who responded to the Community Tracking Physician Survey in 2000 and 2001.	Patients were retrospectively attributed to physicians using the following approaches: 1. Plurality Algorithm- Patients were assigned to the physician (or practice) with whom they had the most EM visits in a given year. To resolve ties, PCPs were prioritized followed by the physician who billed for the greatest number of charges.
		2. Plurality PCP algorithm- excludes specialists and assigns patients on the basis of primary care EM visits
		3. Majority provider algorithm- assigns patients according to the plurality of EM visits with the additional criterion that plurality must be at least 50%
		4. Multiple provider algorithm- patients were assigned to all providers who billed for at least 25% of their EM visits
Ramsey GW. Evaluating policies using agent–based simulations: investigating policies for continuity of care. International Journal of Simulation and Process Modelling. 2014; 9(4): 255-269.	This study uses agent-based simulations to evaluate different approaches to promote the continuity of care for patients with type 2 diabetes.	Patients were attributed to physicians using one of the following approaches: 1. Continuous care- each patient is randomly assigned a specific physician model for continuous care across visits
		2. Opportunistic care- each patient on each visit is opportunistically (randomly) assigned to a physician
Scholle S, Roski J, Dunn D. Availability of data for measuring physician quality performance. Am J Manag Care. 2009; 15(1):67-72.	This study evaluates how different attribution approaches influence the availability of data to assess the quality of care provided by PCPs.	The following methods to attribute patient measures to PCPs were evaluated in the study: 1. A patient was attributed to a physician if the patient had 1 or more visits during the time period
		2.Patients were retrospectively attributed to physicians that conducted at least 30% of ambulatory visits
		3. Patients were retrospectively attributed to physicians that conducted at least 50% of ambulatory visits
Scholle SH, Roski J, Dunn DL, et al. Availability of data for measuring physician quality performance. Am J Manag Care. 2009; 15(1):67–72.	This articles evaluates physician quality performance using administrative data from 9 health plans.	The following retrospective attribution approaches were analyzed: 1. A patient was attributed to a PCP if the patient had 1 or more outpatient visits during the prescribed time frame.
		2. A patient was attributed to a physician if the patient completed at least 30% of his or her ambulatory visits with that physician.
		3. A patient was attributed to a physician if the patient completed at least 50% of his or her ambulatory visits with that physician.
Sharma G, Fletcher K, Zhang D. Continuity of outpatient and inpatient care by primary care physicians for hospitalized older adults. JAMA. 2009; 301(16): 1671-80.	This article examines the continuity of care in hospitalized Medicare patients.	Patients were attributed using two approaches: 1. Beneficiaries were retrospectively attributed to the PCPs (a general practitioner, family physician, general internist, or a geriatrician) who had billed an outpatient EM code for the patient on three or more occasions in the year prior to the hospitalization.
		2. Beneficiaries were also retrospectively attributed to any physician who had billed at least one outpatient EM code in the prior year.
Thomas JW. Economic profiling of physicians: does omission of pharmacy claims bias performance measurement? Am J Manag Care. 2006;12(6):341–351.	This article evaluates the development of physician economic profiles using pharmaceutical claims.	Patients were retrospectively attributed to physicians using claims data: 1. Physicians accounted for at least 50% of the combined professional and prescribing costs
		2. Physicians accounted for at least 30% of the combined professional and prescribing costs
		3. Physicians accounted for at least 50% of professional costs
		4. Physicians accounted for at least 30% of professional costs
Thorpe C, Johnson H, Dopp A. Medication oversupply in patients with diabetes. Res Social Adm Pharm. 2015; 11(3): 382-400.	This study analyzes the supply of medications among diabetes patients managed by a large, multispecialty physician group.	The study analyzed the following approaches: 1.Plurality Provider Algorithm- Patients were prospectively attributed to the group accounting for the greatest number of EM visits in a given year;
		2. The "Diabetes Care Home" method- Patients were attributed to a provider group in a given year if they had ≥2 EM visits to a PCP or one visit to a PCP and one visit to an endocrinologist, over the current and prior year.
Wagner E, Coleman K, Reid RJ, Phillips K, Sugarman JR. Guiding Transformation: How Medical Practices can Become Patient-Centered Medical Homes: The Commonwealth Fund. 2012. Retrieved from http://www.collaboration healthcare. com/7-24-12CommonwealthMedicalPracticeto MedicalHomeFebruary2012.pdf	This reports provides guidelines on how to establish patient-centered medical homes	Patients are prospectively attributed to a PCP using the following steps: 1. Assign all patients who have only ever seen one provider to that provider. 2. Develop a list of patients with their last three to five providers seen. 3. Assign patients who have seen a provider the majority of times to the majority provider. 4. Allow clinic teams to talk through the rest of the patients and where they belong. Providers and patients then review assignments and approve links.

Citation	Description	Attribution Method
Other		
Cebul RD. Using electronic medical records to measure and improve performance. Trans Am Clin Climatol Assoc. 2008; 119:65–75.	This study analyzes the use of EMRs to measure the quality of primary care.	Patients were retrospectively attributed to a PCP according to where they received the majority of EM visits. PCPs then confirmed that the patients attributed to them were their patients.
Garnick DW, Fowles J, Lawthers AG, Weiner JP, Parente ST, Palmer RH. Focus on quality: profiling physicians' practice patterns. J Ambul Care Manage. 1994; 17(3):44–75.	This article describes the use of Medicare data to develop physician practice profiles.	Patients were retrospectively attributed to a PCP (internist, family practitioner, general practitioner) who provided the majority of care in terms of "face-to-face" visits. Total charges were used to resolve ties.
Hillman BJ, Olson GT, Griffith PE, Sunshine JH, Joseph CA, et al. Physicians' utilization and charges for outpatient diagnostic imaging in a medicare population. JAMA. 1992; 268(15):2050–54.	The article analyzes physicians' utilization of and charges of diagnostic imaging.	Patients were attributed to the nonradiologist provider who submitted a claim for the index imaging study. If no claims were submitted by nonradiologists, patients were attributed to the provider who referred the patient to a radiologist.
Hussain T, Chang H, Veenstra C, Pollack C. Fragmentation in specialist care and stage III colon cancer. Cancer. 2015; 121(18):3316-24.	This study explores whether receiving oncology care at more than one hospital is associated with cost and outcomes.	Patients were attributed to a provider in each of the following categories: 1. For surgical care, the operative surgeon was identified as the patient's surgeon, and the location of the procedure was the patient's surgical hospital. For the patients who had more than 1 colon cancer surgery, the assignment of surgical care was based on the first operation.
		2. For oncologic care, patients were assigned to the medical oncologists who billed for the plurality of their visits in the year following their diagnosis and were then designated the hospital at which these oncologists were most likely to practice. Oncologists were assigned to the hospital at which they billed for the most inpatient care. Oncologists who did not bill any inpatient claims were assigned to the hospital to which most of their patients were admitted.
Kralewski J, Dowd B, Knutson D, Tong J, Savage M. The relationships of physician practice characteristics to quality of care and costs. Health Serv. Res. 2015; 50(3):710–29.	This study analyzes the association between practice characteristics and quality	Beneficiaries were retrospectively attributed to practices if they received a plurality of their nonhospital evaluation and management (E&M) visits from a physician associated with the practice
Nyweide D, Weeks W. Relationship of primary care physicians' patient caseload with measurement of quality and cost performance. JAMA. 2009; 302(22):2444-50.	This study analyzes whether PCPs see sufficient numbers of patients to detect meaningful differences in the quality of care they provide to Medicare patients.	Patients were retrospectively attributed to all PCPs (defined as defined as internists, family practitioners, general practitioners, or geriatricians) in which they had a least one outpatient visit.
O'Malley A. Interspecialty communication supported by health information technology associated with lower hospitalization rates for ambulatory care–sensitive conditions. J Am Board Fam Med. 2015; 28(3): 404-17.	This article analyzes the association between primary care practice capabilities and hospitalizations for Medicare patients with certain chronic diseases.	Beneficiaries were retrospectively attributed to the physician who provided the plurality of their outpatient EM visits. Emergency physicians, hospitalists, surgeons, and certain medical subspecialties unlikely to serve as a patient's usual PCPs were excluded
Perloff J. Comparing the Cost of Care Provided to Medicare Beneficiaries Assigned to Primary Care Nurse Practitioners and Physicians. Health Serv Res. 2015; In Press.	This article analyzes differences in the cost of care provided to Medicare patients assigned to NPs and physicians.	Beneficiaries were retrospectively attributed to the single largest provider (pcp) of EM services in terms of cost. A 30% minimum threshold was imposed. In order to resolve ties, one pcp was randomly selected.
Perloff J, Meagher J, Bishop C, Tompkins C. Time to Readmission Among Chronically Ill Community-Resident Beneficiaries: Variations by Geographic Area and Provider Type FINAL Report. 2010. Retrieved from https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/Reports/downloads/perloff_commdwellers_adverseeventschronillness_2010.pdf.	This report assesses the affect of continuity of care on the likelihood for readmissions among chronically ill patients.	Beneficiaries were retrospectively attributed to the single largest provider of EM services.
Peterson G, Xia Z, Hughes J, Wilcox L. Working Paper: Rewarding Physicians for Their Patients' Health Outcomes: What can Medicare Learn from Education's Value-Added Models. Mathematica Policy Research. 2012. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.261.3604&rep=rep1&type=pdf.	This report draws from education research to assess how approaches to reward teacher performance can be applied to value-based purchasing in health care.	Patient were retrospectively attributed only to the doctor who provided the most EM services to that patient during the year.
Romaire M, Haber S, Wensky S, McCall N. Primary care and specialty providers: an assessment of continuity of care, utilization, and expenditures. Med Care. 2014; 52(12): 1042-9.	This study analyzes health service use among Medicare patients by primary provider type (PCP or specialist).	Beneficiaries were attributed to the PCP who the beneficiary saw for the plurality of their FFS EM ambulatory visits. Attribution could be made to a PCP or certain types of specialist physicians.
Weiner JP, Parente ST, Garnick DW, Fowles J, Lawthers AG, Palmer RH. Variation in office-based quality. a claims-based profile of care provided to medicare patients with diabetes. JAMA. 1995; 273(19):1503–8.	This study conducts physician profiles for diabetes care to analyze variations in quality	Beneficiaries were retrospectively attributed to the PCP who provided more face-to-face office visits than any other provider or group. Ties were resolved by assigning patients to the PCP who provided the most intensive services (as defined by the relative value of visits and procedures).

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