Supplementary Appendix

Table of Contents

Validation

Reviewers expressed concerns about the validity of our methodology to identify indirect billing. More specifically, is it reasonable to assume that a prescription signals who largely provided the care in a visit?

Building on our prior published paper where we first introduce this methodology, in the revised BMJ manuscript we have addressed this concern in the following ways:

1. We acknowledge in the manuscript that there are no additional studies in the peer-reviewed literature that compare the clinician who prescribed a medication to the clinician who provided care using the same data source (direct observation or electronic health record data).

2. We conducted a new analysis to bolster confidence in the validity of our method to identify indirectly-billed visits provided to Medicare patients. Using e-prescribing and administrative health insurance claims data from an electronic health record company in the US preferentially used by smaller primary care practices, we identified all prescriptions associated with an office visit in the most recent year (2017) of available data (60+ million visits).

   For each visit with an associated prescription, we identified which clinician (a) prescribed the medication, (b) rendered the visit (i.e., was listed as the provider in the electronic health record), and (c) submitted this bill to the insurer. A directly-billed visit is where the rendering and billing clinician match. An indirectly-billed visit is where there is a difference between the rendering clinician and the billing clinician.

   Of all NP/PA visits among the practices using this EHR, 51.4% were billed indirectly. This is consistent with the results from our prior Health Affairs paper where using Medicare claims, we estimated the fraction of NP/PA visits billed indirectly was 54.3% in 2010 and 37.8% in 2018. We believe the estimate of indirect billing is slightly higher in the EHR data than in Medicare claims, because smaller primary care practices are preferentially more likely to use this EHR. Relatedly, in our Health Affairs paper, we also found that smaller practices were more likely to use indirect billing.

   We then calculated the share of directly-billed and indirectly-billed visits where the visit's rendering clinician matched the prescribing clinician (Table below). For the vast majority (>95%) of NP-rendered and PA-rendered visits, the clinician on the prescription matched the clinician who rendered the visit. This supports the methodological approach we have taken in the paper.

   We note that in 2.7% of all physician visits, the rendering physician and billing physician were not the same. This happened almost entirely in the context of supervision of residents where the resident provided the visit, but the attending physician billed the visit. In this context, we see that the attending physician was more likely to prescribe the medication (only 92.4% of the prescriptions were written by the resident).

   Finally, in the EHR data, we find that 32.4% of all visits are provided by NPs or PAs. This is consistent, albeit slightly higher, with the estimate from our BMJ paper. We believe the rate is higher, because the practices that use this EHR are more likely to be smaller primary care practices who are more likely to employ NPs and PAs.

Table. Fraction of visits in which the rendering clinician and the prescribing clinician are the same.

	Directly billed visits	Indirectly billed visits
Nurse Practitioner	8,216,447 (97.5%)	5,874,938 (96.3%)
Physician Assistant	2,535,000 (96.2%)	4,151,336 (96.0%)
Physician	42,663,126 (96.4%)	1,143,318 (92.4%)

Unfortunately, there are limitations on what data we can make public and therefore we did not include these additional results in the manuscript or appendix. The EHR data were provided to us under a restricted data use agreement and the EHR company does not want to make these public, because they are concerned that the data could increase scrutiny of the use of indirect billing among their clients. If BMJ is interested in publishing this article, we would ask that we work with BMJ to make some changes to the published response letter (e.g., removing the name of the EHR vendor).

3. We have added text to our BMJ paper emphasizing that our estimates of indirect billing are similar to prior work:
    a. "Our estimates of the frequency of indirect billing (38 percent to 54 percent, depending on the year) are consistent with prior estimates from electronic health record–based methods (51 percent of primary care NP visits were billed indirectly)."
    b. "We also note that our estimate is similar, albeit higher, to a prior survey of primary care NPs which found that 29 percent of primary care NPs reported that they bill indirectly."
4. Finally, we highlight that our estimate of the fraction of all visits provided by NP/PAs in the US is similar, albeit slightly lower, than the fraction of clinicians that are NP or PAs, "Based on data from the Bureau of Labor statistics, 29.6% of these three types of clinicians (NPs, PAs, physicians) are NPs or PAs. In this manuscript, we estimate that 25.6% of visits are provided via NPs or PAs. This would imply that per clinician, NPs and PAs see fewer Medicare patients than physicians, which is consistent with prior literature (Liu and colleagues, 2020; doi:10.1111/1475-6773.13246; Neprash and colleagues, 2020; doi: 10.1097/MLR.0000000000001404).
5. As recommended by a reviewer, we have added a figure to the Appendix explaining the methodology in more depth.

The limitations of our approach also emphasize a key motivation for our paper and why we believe it to be an important addition to the literature. To date, because of indirect billing, it has been almost impossible to accurately quantify the involvement of NPs and PAs in the US health care system. In a recent article, NPs described that they played an "invisible role" in the health care system. Even if we could publish the results from a single EHR vendor or large health system, those results would have limited generalizability. We believe the results in our BMJ paper provides the first population-level estimates for the increasing involvement of NPs and PAs in care delivery and what role they are playing. This, in turn, can inform a conversation about the implications of this relatively dramatic shift in care.

The relative role of NP/PAs vs. MDs in visits

Reviewers appropriately pushed back at how we classified visits in a strictly dichotomous manner – NP/PA visits vs. physician visits. It can be more nuanced. In a visit where the NP or PA plays the primary role, a physician may provide input and even physically see the patient. We should also note that this is true in visits where the physician is the primary provider. For example, a NP or PA could take the initial history and then the physician could supplement the history, conduct the physical exam, and make a treatment recommendation.

To address this concern, we have made the following changes.

(1) We raise this issue directly in a new section in the methods where we acknowledge that physicians, NPs, and PAs often work together in complex ways. We clarify that when we label the visit, we are aiming to capture primary provider for the visit, but that other clinicians may be involved.

> The relative role of the NP, PA, and physician will also vary in individual visits. There are billing guidelines, but there has been substantial ambiguity and controversy about what is required for an indirect bill. In many cases, the physician does not see the patient and is not involved in the diagnosis and management. In some cases, the supervising physician may provide advice to the NP or PA at the time of the visit, but not physically see the patient. Physicians may also physically see the patient and play a more substantive role, particularly for visits in skilled nurse facilities. Consistent with recent guidelines by the US federal government, when we label a visit as a NP/PA visit, we assume that the visit is assigned to the clinician who spends majority of time spent in history taking, physical exam, decision making, and management.

(2) To better characterize the relative role of NPs and PAs across conditions and types of visits, we included several analyses in the manuscript. We measure fraction of different types of visits delivered by NPs and PAs. We do this using the billed code (e.g., annual exam, follow-up visit, new patient visit) (Table S5 in Appendix). We also measure the fraction of visits delivered by NP/PA for different conditions (Table S4 in Appendix).

(3) In the discussion, we summarize these findings and the larger point:

> However, our results do not support the idea that NPs and PAs are simply replacing physicians in a one-to-one fashion. Rather they play a more complementary role with a greater focus on some types of visits. Across conditions, we observe substantial differences in the involvement of NP and PAs with higher involvement in low-acuity acute problems (for example, respiratory infections and urinary tract infections) and mental illness, and a lesser role for heart disease and eye disorders. NPs and PAs are more likely to provide new patient visits and less likely to provide annual exams. Surprisingly, we found that in areas of the United States with fewer physician visits per capita there were also fewer NP and PA visits per capita. We hypothesize that this reflects a shift to team-based care where multiple clinicians can be involved in a single visit. Our findings echo prior work where there is substantial variation in the role of NPs and PAs in multidisciplinary teams including patient counseling, educational services, and the provision of full primary care services.[28-31] More research is needed to understand the different configuration of practices, how NPs and PAs are integrated into models of care, and if there are optimal models in terms of the quality of care delivered.[32-35]

(4) While we acknowledge that sometimes the case that physicians play an important role in NP and PA visits (e.g., also interviewing the patient, making clinical decisions), we also push back on the perception that physicians play a substantive role in most NP or PA visits. Rather, it is common for the NP and PA to provide care fully independently. In the Appendix, we state:

> The relative role of the NP, PA, and physician will vary in individual visits. In many cases, the physician does not see the patient and is not involved in the diagnosis and management of the patient.[10,11] In other visits, the supervising physician may provide advice to the NP or PA at the time of the visit but does not physically see the patient. Physicians may also physically see the patient and play a more substantive role, particularly for visits in skilled nursing facilities. There has been substantial ambiguity and controversy about the billing guidelines and what is required when a visit is billed indirectly by a physician.[12]

(5) In the discussion, we acknowledge this limitation of our analysis and we have tempered our language throughout to recognize this issue.

Methods

A. Details on direct and indirect billing

Indirect billing was originally implemented to offset the costs for physicians of supervising NPs and PAs caring for Medicare beneficiaries. In administrative claims or "billing data" in the United States, the billing clinician listed on each claim may not reflect the clinician who provided the care due to indirect billing. In indirect billing, a visit is provided by NPs and PAs but billed under the supervising physician (as identified by the National Provider Identifier (NPI). In these data, a visit billed indirectly, and a visit billed directly by the physician are indistinguishable.

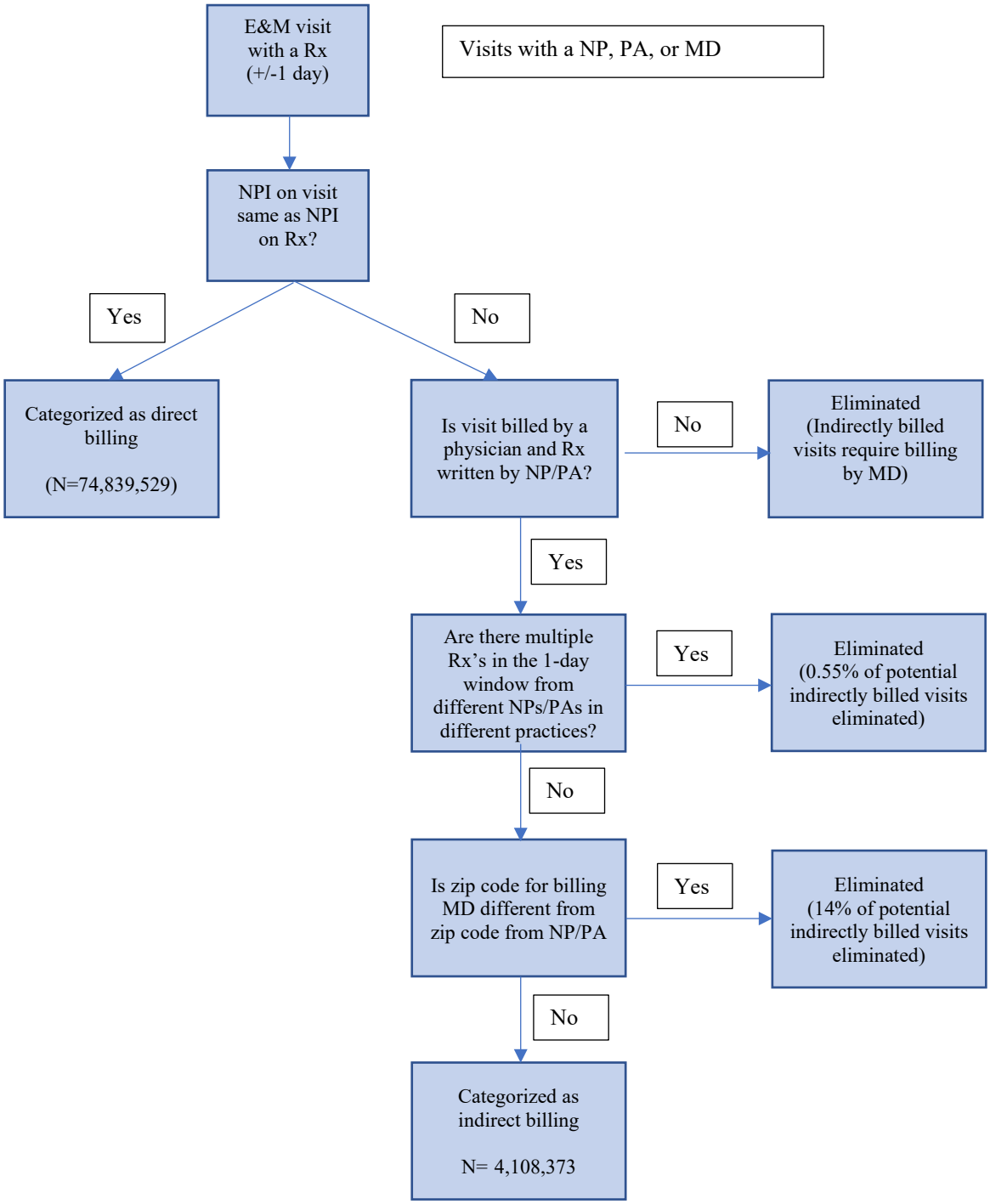
Our previously published method (Patel and colleagues, 2022, Health Affairs) assumes that the prescription associated with a visit can identify who primarily cared for the patient. During a visit where the physician cared for the patient, both the prescription and claim for the visit are under the physician's NPI. However, for NP and PA visits billed indirectly, the prescription is under the NP or PA's NPI but the claim for the visit is under the physician's NPI, and therefore the visit is misclassified as a physician visit.

There are two types of indirect billing that involve NPs and PAs, incident-to and shared visits. Both capture circumstances where NPs and PAs are involved in the delivery of care, but they are used in different clinical settings and there are, potentially, differences in the role of the physician in these visits. Incident-to billing is used in the office or clinic setting. Current rules dictate that the supervising physician must be physically on site and be available for assistance and advice. Whether this is followed is less clear as surveys of NPs highlight that the physician may not be on site.[1,2] A shared visit is an encounter in the hospital wherein a physician and a non-physician practitioner (NPP) or a physician assistant (PA) both see the patient.[3] For CY 2023, the Centers for Medicare and Medicaid finalized policy for shared visits, determining that the clinician who spends more than half of the total time delivering care to the patient should bill for the visit.[4]

The following elements should be considered when determining the total time for care:

- History.
- Performing a physical exam.
- Medical Decision Making.
- Spending time (more than half of the total time spent by the practitioner who bills the visit).

B. Sample Size Diagram (unweighted sample)



C. Measuring volume of visits delivered by NP/PA/MDs

We separately measure visits per patient for NPs, PAs, specialty physicians, and primary care physicians. The numerator is the number of visits delivered by each clinician each year (indirectly and directly billed for NPs and PAs). The denominator is the total number of patients each year. Second, we have added additional detail regard how our fraction of total visits delivered by NPs and PAs was created

We separately measure the fraction of total visits delivered for each clinician. The denominator is the number of visits in our sample provided by NPs and PAs (both indirectly and directly billed) and physicians (specialty and primary care physicians). The numerator is the number of these visits billed for each clinician (indirectly and directly billed visits for NPs and PAs).

D. Glossary Defining Medicare Data

Medicare Eligibility:
Medicare is the health insurer for people 65 or older, those permanently disabled, those with end-stage renal disease, or amyotrophic lateral sclerosis.

Traditional Medicare vs. Medicare Advantage:
Traditional Medicare (also known as Medicare fee-for-service) is run by the US government whereas Medicare Advantage is the private insurance alternative to Traditional Medicare.

Under original Medicare, a member can choose any providers — primary care doctors and specialists who accept Medicare. A member does not need referrals to see any medical provider and they do not have to worry about your doctor leaving a plan's network. According to the Kaiser Family Foundation, only 1 percent of doctors do not participate in Medicare, and, for example, 83 percent of primary care physicians accept new Medicare patients.

Under Medicare Advantage, a patient is joining a private insurance plan like an employer plan. The most common ones are health maintenance organizations (HMOs) and preferred provider organizations (PPOs). Medicare Advantage employs managed care plans, and, in most cases, a member would have a primary care physician who would direct their care, meaning they would need a referral to a specialist. HMOs tend to have more restrictive choices of medical providers than PPOs.

From 2013-2019, proportion of all Medicare members using Medicare Advantage vs. Traditional Medicare has increased from 29% in 2013 to 39% in 2019.[5]

Definition of Medicare FFS Data:
Traditional Medicare has three parts Part A (hospital care), Part B (doctor visits, lab tests and other outpatient services), and Part D (prescription drugs).

Definition of 20 percent random sample:
This is data purchased from the Centers of Medicare and Medicaid (CMS). This is not publicly available data. The HMS Department of Health Care Policy houses a random sample of

approximately 20 percent of all Medicare beneficiaries with fee-for-service coverage of Medicare Parts A, B, and D.

E. Use of NP/PAs in other countries

Volume of NPs in other countries:

	NPs per 100,000 population	Physicians per 100,000 population
United States	40.5	250
Netherlands	12.6	416
Canada	9.8	255
Australia	4.4	395
Ireland	3.1	270
New Zealand	3.1	304

Maier CB, Barnes H, Aiken LH, Busse R. Descriptive, cross-country analysis of the nurse practitioner workforce in six countries: size, growth, physician substitution potential. BMJ Open. 2016;6(9): e011901. Published 2016 Sep 6. doi:10.1136/bmjopen-2016-011901

Volume of PAs in other countries:

TABLE 1. - An estimated global PA census as of mid 2020

Country	PAs	Year of first PA graduation	Number of PA programs
Australia	30	2011	1
Bulgaria	100	2017	3
Canada	750	2012	4
Germany	1,000	2005	13
Ghana	3,000	1971	3
Guyana	75	1978	1
India	1,500	1994	30
Ireland	28	2017	1
Israel	70	2017	1
Liberia	1,200	1967	3
Netherlands	1,400	2003	5
New Zealand	10	0	0
Poland	3	2019	1
Saudi Arabia	--	2008	1
South Africa*	1,300	2010	3
Switzerland	60	2007	1
United Kingdom**	2,000	2004	35
United States***	120,000	1967	260
Total (estimated)	132,526		366

Hooker, Roderick S. PhD, PA; Berkowitz, Oren PhD, PA-C. A global census of physician assistants and physician associates. JAAPA 33(12):p 43-45, December 2020. | DOI: 10.1097/01.JAA.0000721668.29693.36

F. Data Source

We used traditional Medicare claims data from 2013-2019. We limited our analysis to adults (ages 18 and older) with 12 months of coverage for hospital care (e.g., emergency department or inpatient setting), medical care (e.g., outpatient setting or nursing facility), and drug coverage in each year.

Given indirectly billed visits occur in the outpatient setting or nursing facilities, our analysis used data from the following three files:

- Master beneficiary file (includes patient demographic and coverage information)
  https://resdac.org/cms-data/files/mbsf-base

- Outpatient (includes visits in hospital outpatient settings):
  https://resdac.org/cms-data/files/op-ffs

- Carrier file (includes visits in office setting or nursing facilities):
  https://resdac.org/cms-data/files/carrier-ffs

- Part D (includes prescriptions):
  https://resdac.org/cms-data/files/pde

G. Identification of visits in the study

We focused on evaluation and management visits in the outpatient, and skilled nursing facility settings as defined using the Restructured Berenson-Egger Type of Service System (RBCF) codes, and CMS place of service codes.

We include all types of visits in the outpatient and nursing facility setting. While Medicare billing rules dictate that indirect billing can be used only after the initial physician relationship has been established, prior work using electronic health records indicates that indirect billing is often used in other types of visits. The setting was determined using the place of service codes below.

	Berenson-Egger Type of Service (BETOS) Code	Current Procedural Terminology (CPT) Codes
Outpatient	EX000N, EV004N, EV001N, EH017N, EV011N	92502, 92504, 92531, 92532, 92533, 92534, 92558, 92620, 92621, 92625, 92626, 92627, 94002, 94003, 94004, 94005, 94664, 95831, 95832, 95833, 95834, 95851, 95852, 95857, 96040, 96160, 96161, 97169, 97802, 97803, 97804, 98960, 98961, 98962, 99002, 99024, 99050, 99051, 99053, 99056, 99058, 99060, 99070, 99071, 99078, 99080, 99082, 99090, 99091, 99170, 99201, 99202, 99203, 99204, 99205, 99211, 99212, 99213, 99214, 99215, 99231, 99232, 99233, 99238, 99239, 99341, 99342, 99343, 99344, 99345, 99347, 99348, 99349, 99350, 99360, 99423, 99444, 99446, 99447, 99448, 99449, 99451, 99452, 99453, 99454, 99457, 99460, 99461, 99463, 99499, 99605, 99606, 99607, G0128, G0302, G0303, G0304, G0305, G0380, G0381, G0382, G0383, G0384, G0402, G0438, G0439, G0451, G0493, G0494, G0495, G0496, G9148, G9149, G9150, G9151, G9152, G9153, G9490, G9679, G9680, G9681, G9682, G9684, Q3014
Visits in nursing facilities	EN008N, EN016N	99304, 99305, 99306, 99307, 99308,99309, 99310, 99315, 99316, 99318, 99324, 99325, 99326, 99327, 99328, 99334, 99335, 99336, 99337

	place of service code
removed inpatient and ED visits	21, 23, 24, 25, 51, 52, 09, 61, 62, 55, 56
Visits in a nursing facility	31, 32, 33, 34, 13, 61
Outpatient setting	00, 01, 02, 03, 04, 05, 07, 08, 11, 12, 14, 15, 16, 17, 19, 20, 22, 41, 49, 50, 53, 54, 57, 65, 71, 72, 81, 99, HOPD

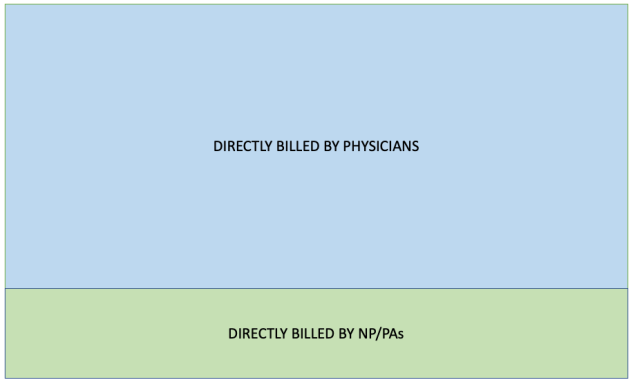
We further categorized visits as care delivered by a primary care physician, specialty physician, nurse practitioner, or physician assistant via the provider specialty code:

	CMS provider specialty code
Primary care physician	01, 08, 11, 37, 38, 12, 84
Specialty physician	16, 06, 93, 29, 39, 10, 46, 44, 26, 20, 13, 25, 02, 83, 34, 66, 04, 05, 09, 07, 18, 03, 14, 17, 21, 23, 24, 27, 28, 33, 40, 72, 76, 77, 78, 79, 81, 82, 85, 86, 90, 91, 92, 98, 99, C0, C3
Nurse practitioner	50
Physician assistant	97

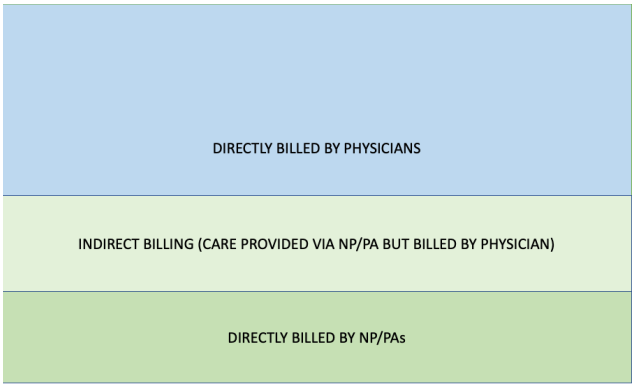
H. Rationale for using inverse probability weighting

Our method for identifying indirect (or "incident to") billing can only be applied to physician visits with a prescription. We use inverse probability weighting to generalize the patterns we find in visits with a prescription to all visits. In this section, we provide more details for why such a weighting method is needed and how it was operationalized. We also describe an alternative method for extrapolating to all visits.

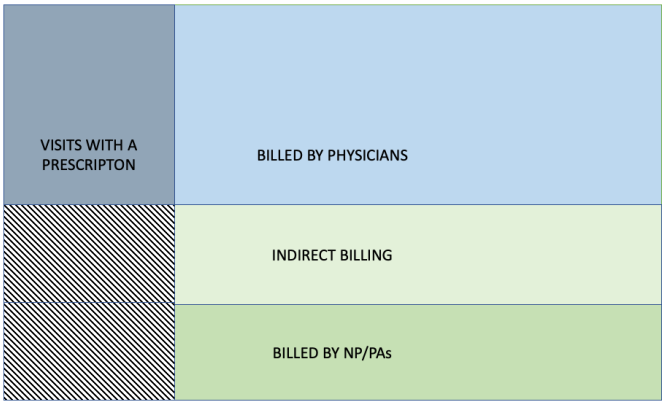
Across all visits in our sample, some visits are directly billed by NP/PAs and some are directly billed by physicians. Directly billed means that the clinician identifier on the bill is from the clinician who provided that care.



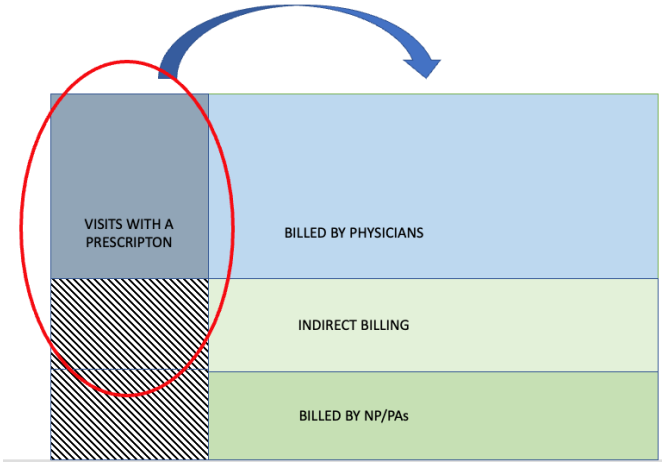
As we discuss in the manuscript, a substantial fraction of the physician visits are indirectly billed or billed "incident to." In other words, the care was provided by a NP/PA, but billed by a physician. We reassign these visits from a physician to a NP/PA. Roughly 40-50% of all NP/PA visits are billed indirectly.



We can only identify indirect billing among visits with a prescription. Those marked by slanted lines below (roughly 25% of visits result in a prescription).



The goal of our primary weighting method is to apply the patterns observed among the visits with a prescription to visits without a prescription. In essence we "fill in" the visits without a prescription.



I. Details on how weights were generated

Method 1: Weights based on probability a visit will result in a prescription

A naïve approach would assume the percentage of visits without a prescription that are billed incident-to a physician is the same as the observed percentage of visits with a prescription that are billed incident-to. This is not necessarily the case.

We know that whether a visit results in a prescription varies substantially by patient and clinical factors. In our predictive model (described below), a visit's predicted likelihood of resulting in a prescription ranges from 1.3 to 75.7%. If we weighted all visits equally, types of visits that are likely to result in a prescription are 'overcounted' in our set of observed visits with a prescription. Thus, to counteract that bias, we wish to weigh visits that are likely to result in a prescription less; conversely, we wish to assign more weight to visits that are unlikely to result in a prescription. ***Method 1 prioritizes the generalizability of visits with a prescription to visits without a prescription.***

It is important to emphasize that assumption we are making. For a given type of visit (e.g., visit with a cardiologist, for atrial fibrillation, in the Northeast, among a 60-65yo woman), we are assuming that the rate of indirect billing observed in visits with a prescription is the same as the rate of indirect billing observed in visits without a prescription.

Procedure Steps:

1. Estimate probability of visit resulting in a prescription using all visits (visits that result in a prescription and visits that do not result in a prescription), regardless of billing provider type.
   Y (prescription yes/no) = B1(clinical factors) + B2(patient factors)
2. Predict the probabilities for visits that result in a prescription using model from Step 1.
3. Calculate weights by taking the inverse of the predicted probabilities.
   a. Apply weights for visits that result in a prescription.
   b. Sum weights to extrapolate findings to total visits (visits the result and do not result in a prescription).

Patient factors: age, sex, race/ethnicity, reason for Medicare enrollment, dual eligibility for Medicaid and Medicare coverage, urban/rural designation, and geography (defined as Census division).

Clinical factors: specialty of billing physician (defined by CMS physician specialty code); BETOS code (defined as evaluation and management visits in the outpatient, or skilled nursing facility setting); condition (defined as the presence of 27 chronic illnesses in each year via the CMS Chronic Conditions Data Warehouse)

In our main analysis, we included the place of service, the procedural code, along with other clinical and demographic patient characteristics, as defined above. However, in a sensitivity analysis, we also included the primary ICD10 diagnosis for the visit, along with the features in the main analysis.

We found minimal differences between estimates for the main model versus the sensitivity analysis that includes the ICD10 primary diagnosis. We did not perform this for all years as it requires substantial compute time and resources.

PA	NP	PCP	Spec MD	Total
No diagnosis (our model)				
0.83	1.71	3.27	4.09	9.89
Includes diagnosis (sensitivity analysis)				
0.81	1.68	3.24	4.05	9.78

J. Sensitivity analysis for extrapolation

Method 2: Estimating the probability a visit will be billed indirectly

As noted above, in Method 1, we are assuming that the rate of indirect billing observed in prescription-related visits of a certain type is same rate of indirect billing observed in visits

without a prescription. To test whether that assumption may be problematic, we used a different method to extrapolate from visits with a prescription to visits without a prescription.

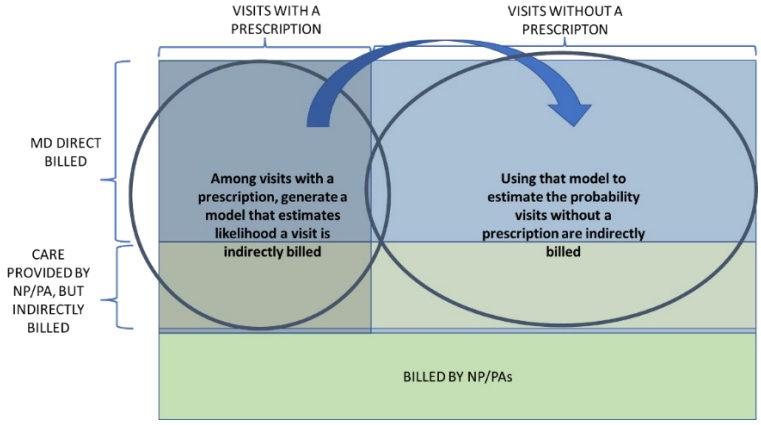
Among physician visits with a prescription, we use the same clinical and provider variables used in the inverse probability weighting to measure the probability that a visit will be billed indirectly. We then turn to visits without an associated prescription. Each visit then contributes to both the indirect and direct billing totals. ***Method 2 prioritizes the generalizability of rates of indirect billing for visits with a prescription to those visits [directly and indirectly billed] without a prescription.***

To be more concrete, in our model, a visit's predicted likelihood of being billed indirectly varies from ~0.0% to 64.2%. For example, for a given type of visit (e.g., visit with a cardiologist, for atrial fibrillation, in the Northeast, among a 60-65yo Black woman, etc.), a physician visit without a prescription has a 35% likelihood of being billed indirectly then it is broken down:

- 0.35 visits by a NP/PA
- 0.65 visits by physician

If a physician visit has a 5% likelihood of being billed indirectly then it contributes as follows:

- 0.05 visits by a NP/PA
- 0.95 visits by physician



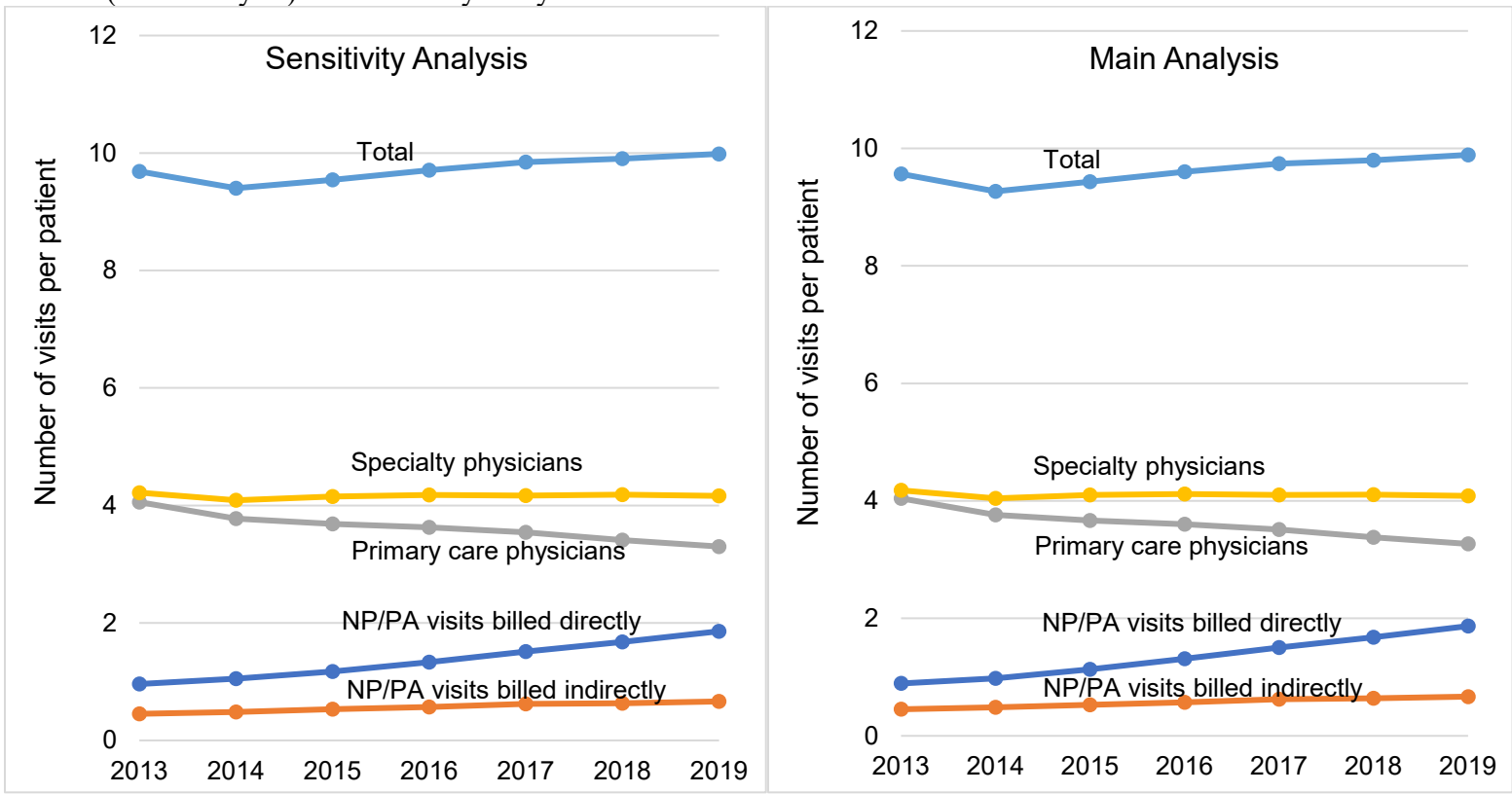
Here we are assuming that the association of clinical and provider factors and indirect billing among visits with a prescription are the same among visits without a prescription. This method, however, is limited in that it cannot assign whether the visit billed indirectly was performed by an NP or PA. This is because we only estimate whether it was indirectly billed. We did not pursue a model with three outcomes (a. directly billed, NP indirectly billed, PA indirectly billed)

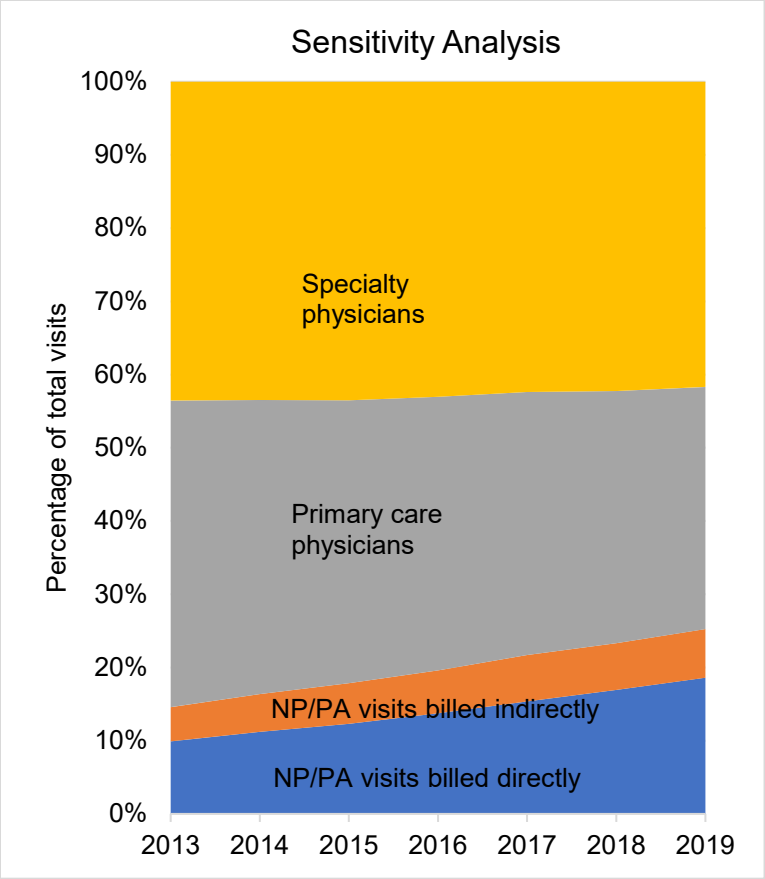
Procedure Steps:

1. Estimate probability of a visit billed indirectly among visits that result in a prescription
   Y (billed indirectly yes/no) = B1(clinical factors) + B2(patient factors)
2. Calculate the predicted probabilities of visits billed indirectly for visits that do not result in a prescription.

Sum probabilities to measure visits billed indirectly for visits that do not result in a prescription.	**Method 1**	**Method 2**
What is predicted?	Likelihood of a prescription	Likelihood of indirect billing
Assumption	Factors associated with billing a visit indirectly are similar across visits with and without a prescription.	For a given type of visit, the rate of indirect billing observed in visits with and without a prescription is the same.

Figure S1: Number of NP/PA visits per patient and percentage of total visits delivered by NP/PAs by inverse probability weighting method (main analysis) vs. sensitivity analysis




Sensitivity Analysis
Percentage of total visits
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Specialty physicians
Primary care physicians
NP/PA visits billed indirectly
NP/PA visits billed directly
2013
2014
2015
2016
2017
2018
2019

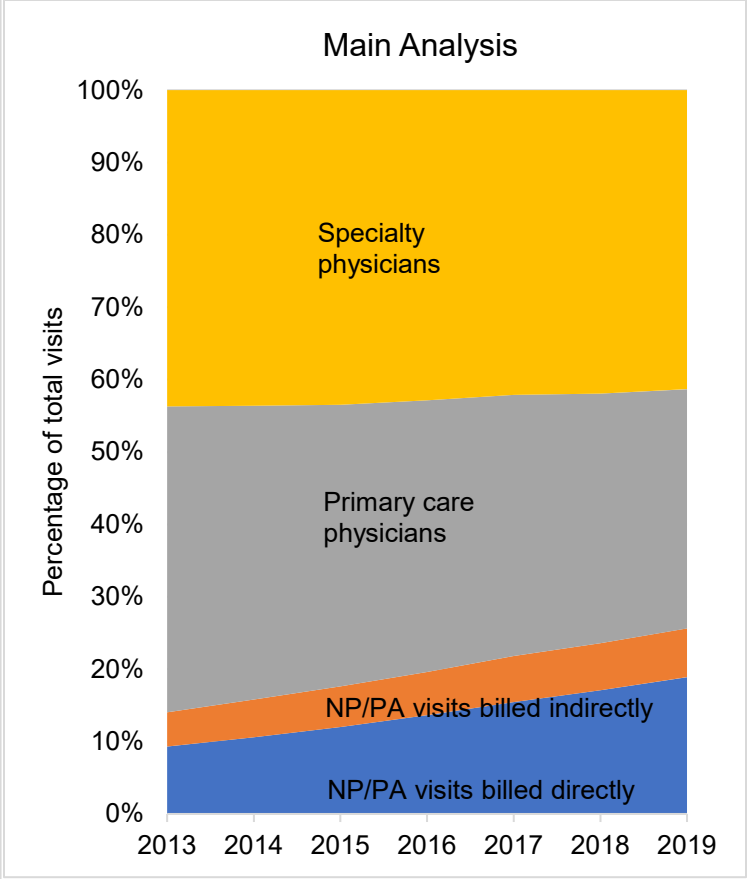

Main Analysis
Percentage of total visits
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Specialty physicians
Primary care physicians
NP/PA visits billed indirectly
NP/PA visits billed directly
2013
2014
2015
2016
2017
2018
2019

Table S1: Characteristics of Patients with at least 1 nurse practitioner (NP) or physician assistant (PA) visit and at least 5 total visits in 2019 (main vs. sensitivity analysis)*

		Main Analysis (at least 1 visit)	**Sensitivity findings (at least 3 visits)**
		Average marginal effect of having at least 1 NP/PA visit vs. none (95% CI)	Average marginal effect of having at least 1 NP/PA visit vs. none (95% CI)
Race/Ethnicity	White	reference category	reference category
	Black	-4.9 (-5.1, -4.7)	-5.6 (-5.9, -5.3)
	Other	-5.8 (-6.2, -5.5)	-5.8 (-6.3, -5.3)
	Asian	-19.0 (-19.3, -18.7)	-24.0 (-24.5, -23.6)
	Hispanic	-5.3 (-5.5, -5.1)	-8.1 (-8.2, -7.5)
	American Indian	5.3 (4.6, 6.1)	3.0 (2.9, 4.9)
Gender	Female	reference category	reference category
	Male	-6.2 (-.63, -6.0)	-5.7 (-5.9, -5.6)
Reason for Medicare enrollment	Old age	reference category	reference category
	Disabled	5.6 (5.5, 5.8)	2.6 (2.4, 2.8)
Dual Medicaid Enrollment	No	reference category	reference category
	Yes	2.9 (2.8, 3.1)	-0.7 (-0.9, -0.5)
Age Category	18-29	12.8 (12.0, 13.5)	19.2 (18.2, 20.2)
	30-39	12.9 (12.5, 13.4)	18.2 (17.6, 18.8)
	40-49	12.6 (9.6, 10.2)	16.3 (15.8, 16.7)
	50-59	9.9 (9.6, 10.2)	12.4 (12.0, 12.7)
	60-64	7.4 (7.0, 7.7)	9.5 (9.1, 9.9)
	65-79	3.8 (3.7, 3.9)	5.5 (5.3, 5.7)
	80 and older	reference category	reference category
Rural	Metro (1M+)	reference category	reference category
	Metro (250K-1M)	10.6 (10.5, 10.7)	12.5 (12.3, 12.6)
	Non-metro, non-rural	15.1 (14.9, 15.2)	15.7 (15.5, 15.9)
	Rural	19.7 (19.4, 20.1)	19.2 (18.8, 19.7)
NP State Scope of Practice Laws	Restricted	reference category	reference category
	Reduced	-0.4 (-0.6, -0.2)	0.4 (0.2, 0.6)
	Full	1.1 (1.0, 1.3)	1.8 (1.6, 2.1)

***** We limited our analysis to patients with at least 3 total visits (physician or NP/PA visits) to ensure stable estimates. We selected 3 as this was the median value in the distribution of total visits.

Figure S2: Number of NP/PA visits per patient and percentage of total visits delivered by NP/PAs by specialty of billing clinician vs. specialty of clinician providing care

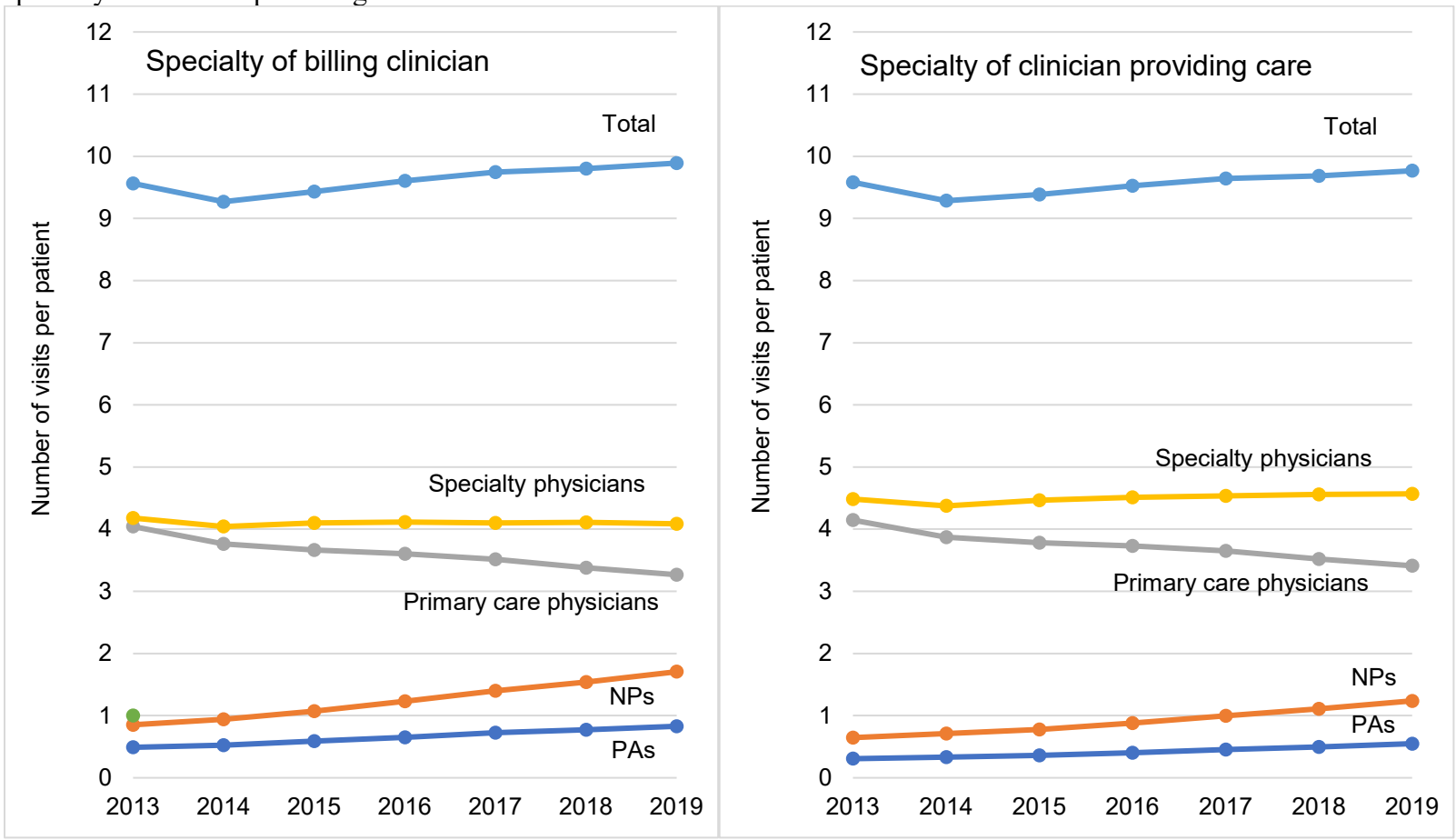
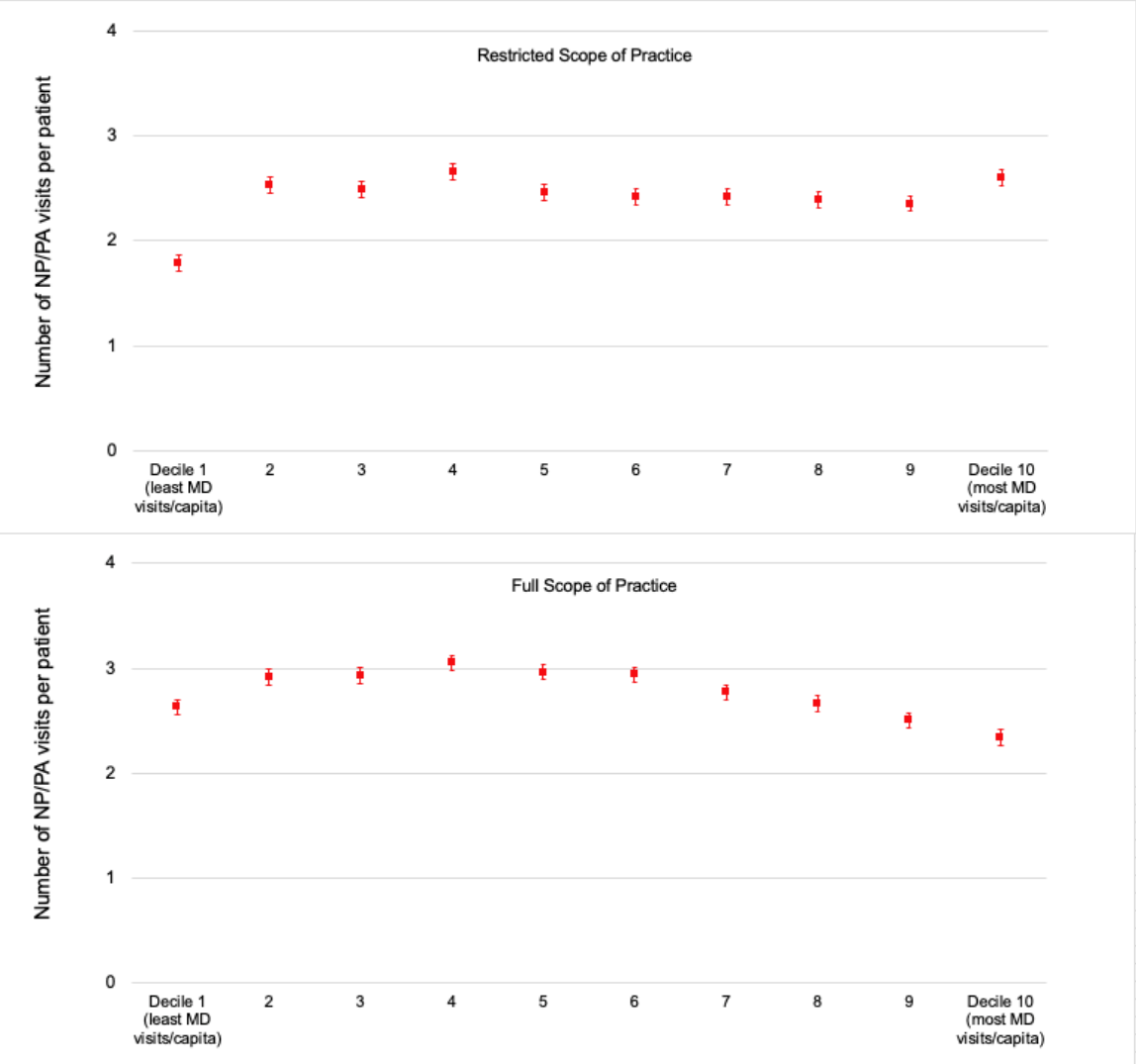


Figure S3: Zip code-level number of nurse practitioner (NP) and physician assistant (PA) visits per patient by deciles of physician visits per patient in 2019 by restricted vs. full NP scope of practice laws*^



*To ensure stable estimates, we eliminated zip codes with fewer than 5 beneficiaries. We selected 5 as this represented the bottom 10 percentile of zip codes for the number of FFS Medicare beneficiaries.
^We present median and IQR for the number of NP/PA visits per patient.

Table S2: Number of visits per patient and percentage of total visits billed directly vs. indirectly

	directly billed by specialty physician	indirectly billed by specialty physician	directly billed by PCP	indirectly billed by PCP	directly billed by NP	directly billed by PA
2013	4.2	0.3	4.0	0.1	0.6	0.3
2014	4.0	0.3	3.8	0.1	0.6	0.3
2015	4.1	0.4	3.7	0.2	0.7	0.3
2016	4.1	0.4	3.6	0.2	0.8	0.4
2017	4.1	0.4	3.5	0.2	0.9	0.4
2018	4.1	0.5	3.4	0.2	1.0	0.5
2019	4.1	0.5	3.3	0.2	1.2	0.5

	directly billed by specialty physician	indirectly billed by specialty physician	directly billed by PCP	indirectly billed by PCP	directly billed by NP	directly billed by PA
2013	43.8%	3.3%	42.4%	1.5%	6.0%	3.1%
2014	43.7%	3.6%	40.7%	1.6%	6.9%	3.4%
2015	43.9%	4.0%	39.2%	1.7%	7.6%	3.7%
2016	43.4%	4.2%	38.0%	1.8%	8.6%	4.1%
2017	42.7%	4.6%	36.6%	1.9%	9.7%	4.6%
2018	42.5%	4.7%	35.0%	1.9%	10.8%	5.1%
2019	42.0%	5.0%	33.6%	1.9%	12.1%	5.5%

Table S3: Fraction of all specialty visits billed indirectly by specialty in 2019*^

CMS specialty code	specialty	indirectly billed visits	total visits	% of total visits billed indirectly
2	General surgery	542,620	2,824,298	19.2%
90	Medical oncology	251,223	1,497,834	16.8%
20	Orthopedic surgery	1,342,919	8,090,113	16.6%
83	Psychiatry	733,917	4,734,336	15.5%
25	Urology	345,812	2,595,068	13.3%
34	Hematology/oncology	552,199	5,518,434	10.0%
C3	Interventional cardiology	185,194	1,852,684	10.0%
16	Obstetrics/gynecology	184,744	1,943,088	9.5%
10	Gastroenterology	304,029	3,348,730	9.1%
29	Pulmonary disease	307,979	3,533,777	8.7%
39	Nephrology	216,379	2,538,230	8.5%
6	Cardiology	910,025	11,133,419	8.2%
46	Endocrinology	211,621	2,610,866	8.1%
7	Dermatology	641,962	8,340,533	7.7%
13	Neurology	311,082	4,124,661	7.5%
4	Otolaryngology	262,399	3,761,577	7.0%
66	Rheumatology	159,794	2,585,261	6.2%
18	Ophthalmology	225,694	3,931,939	5.7%
26	Pain Management	181,050	4,211,625	4.3%
99	Unknown Physician Specialty	118,547	3,324,518	3.6%

*We focused on top 20 specialties as they accounted for 85.7% of all specialty visits

^Estimates were multiplied by 5 to measure visit volume for the 100% Medicare sample

Table S4: Fraction of visits delivered by NPs/PAs by condition in 2019*

* Visits were categorized by diagnosis using the Clinical Classification Software Refined (CCSR) system and the primary diagnosis for the visit.

For example, 20.4% of visits with a primary diagnosis were delivered by an NP or PA, where has 79.6% of visits were delivered by a physician.

	% of visits delivered by NP/PAs
Hypertension*	20.4
Diseases of the heart*	18.2
Spondylosis*	27.7
Diabetes mellitus with complication*	21.8
Diseases of the urinary tract*	30.2
Respiratory infection*	41.5
Non-traumatic joint disorders*	23.9
Genitourinary signs and symptoms*	28.7
Other lower respiratory infection*	31.1
Chronic obstructive pulmonary disease*	27.9
Other connective tissue*	26.7
Other nervous system*	30.2
Mood disorders*	33.8
Eye disorders*	13.2
Other skin disorders*	26.7
Ear conditions*	30.4
Disorders of lipid*	18.2
Other gastrointestinal*	26.3
Other inflammatory conditions*	23.1
Skin and subcutaneous*	38.0
Anxiety disorders *	36.7
Other upper respiratory*	23.2
Upper gastrointestinal*	23.4
Diseases of male genitals*	14.6
Delirium dementia*	27.1
Thyroid disorders*	21.6
Hereditary	17.7
Diseases of arteries	24.4
Cancer of breast	19.9
Asthma	20.7
Schizophrenia	37.9
Cancer of lymphatic a	21.6
Diseases of female genitals	24.1
Fractures	29.4
Viral infection	31.0
Cerebrovascular disease	20.2
Anemia	24.9
Diseases of veins	26.1
Benign neoplasms	21.5
Mycoses	35.9
Cancer of male genitals	16.0
Headache	22.7
Other nutritional	25.7

Substance-related disorder	26.7
Cancer of skin	17.0
Neoplasms of unspecified	21.2
Cancer of bronchus	22.5
Epilepsy; convulsions	20.5
Immunizations	21.9
Lower gastrointestinal	20.8
Complications	20.9
Open wounds	42.2
Superficial injury;	40.0
Sprains and strains	29.4
Chronic ulcer of skin	34.4
Gout	27.2
Colorectal cancer	20.6
Osteoporosis	17.0
Other injuries	34.8
Cancer; other primary	19.9
Nutritional deficiency	25.4
Acquired deformities	24.1
Cancer of urinary organs	17.3
Systemic lupus erythematosus and connective tissue disorders	12.1
Fluid and electrolyte	28.3
Other endocrine disorder	17.9
Diseases of mouth	29.2
Other bone disease	21.9
Respiratory failure	21.0
Gastrointestinal hemorrhage	21.9
Liver disease	24.6
Secondary malignancies	21.7
Noninfectious gastroenteritis	25.8
Miscellaneous mental	27.7
Coagulation and hemorrhaging	22.2
Disorders of teeth	45.1
Joint disorders	20.7
Abdominal hernia	27.8
Attention deficit disorder	33.4
Bacterial infection	25.0
Maintenance chemotherapy	21.1
Cancer of ovary	23.3
Paralysis [	23.5
Cancer of uterus and	25.7
Adjustment disorders	35.5
Intestinal infection	29.7
Other infections;	34.1
Immunity disorders	16.6
Infective arthritis	19.9
Alcohol-related disorder	29.7
Biliary tract disease	25.1
Diseases of white blood cells	33.2
Disorders usually dia	29.5
Developmental disorder	31.6
Pancreatic disorders	22.5
Pleurisy; pneumothorax	27.0
Other specified and unspecified hematologic conditions	25.6

Burns	43.4
Intracranial injury	24.9

Table S5: Fraction of PCP and NP/PA visits delivered by procedure in 2019**

BETOS	PCP*	NP/PA^	Specialty Physician***
Home E&M - New and Established	0.5%	0.3%	0.9%
SNF E&M	4.1%	5.7%	11.4%
Rest Home E&M	1.8%	1.0%	3.2%
Office E&M - Established	79.6%	81.3%	78.3%
Office E&M - New	11.9%	8.8%	4.0%
Annual Wellness Visits	0.5%	1.6%	0.6%
Miscellaneous	1.7%	1.4%	0.6%

**Estimates use weighted sample
*Denominator is total number of visits delivered by a PCP
^Denominator is total number of visits delivered by a NP/PA
***Denominator is total number of visits delivered by a specialty physician

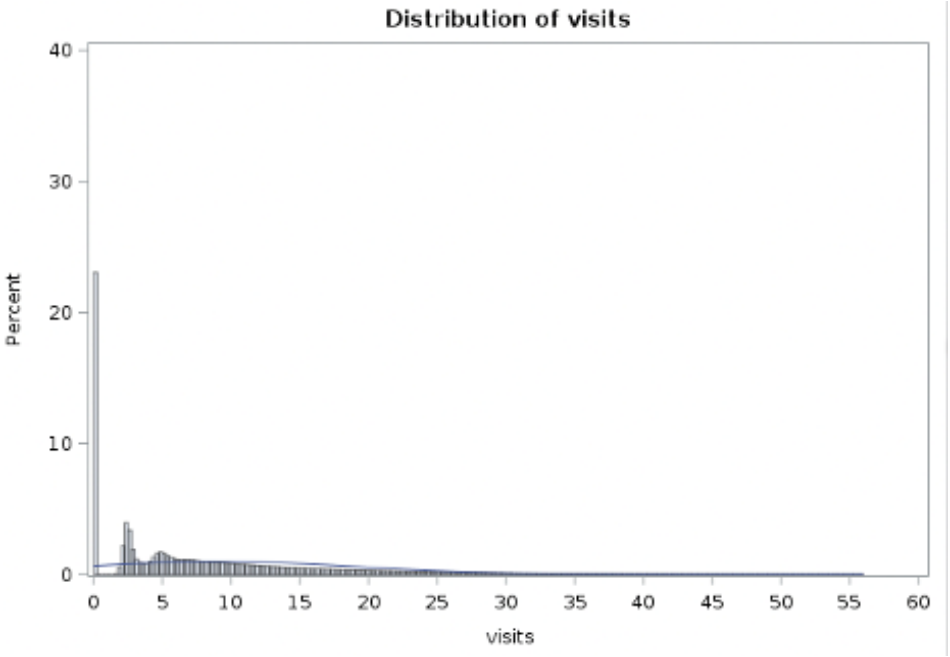
Table S6: Number of NP, PA, PCP, and specialty physician visits per patient [including 95% confidence intervals]

	PA			NP			PCP			Specialty MD			Total		
	mean	95% CI		mean	95% CI		mean	95% CI		mean	95% CI		mean	95% CI	
2013	0.490	0.488	0.493	0.853	0.848	0.858	4.042	4.028	4.057	4.179	4.148	4.211	9.565	9.512	9.618
2014	0.526	0.523	0.529	0.939	0.934	0.944	3.761	3.748	3.775	4.042	4.012	4.073	9.269	9.217	9.322
2015	0.589	0.586	0.592	1.074	1.069	1.080	3.666	3.653	3.679	4.102	4.071	4.132	9.431	9.379	9.483
2016	0.652	0.649	0.655	1.231	1.225	1.237	3.605	3.593	3.617	4.116	4.086	4.146	9.604	9.552	9.655
2017	0.726	0.722	0.729	1.401	1.394	1.408	3.514	3.502	3.526	4.102	4.073	4.132	9.743	9.692	9.795
2018	0.772	0.768	0.776	1.542	1.534	1.549	3.378	3.367	3.390	4.108	4.079	4.137	9.800	9.749	9.852
2019	0.829	0.825	0.833	1.706	1.698	1.715	3.267	3.256	3.279	4.087	4.058	4.117	9.890	9.838	9.943

Table S7: Number of NP and PA visits by setting [including 95% confidence intervals]

	2013			2014			2015			2016			2017			2018			2019		
	mean	95% CI		mean	95% CI		mean	95% CI		mean	95% CI		mean	95% CI		mean	95% CI		mean	95% CI	
Office	1.236	1.230	1.242	1.333	1.326	1.341	1.497	1.489	1.505	1.686	1.678	1.694	1.892	1.883	1.901	2.035	2.025	2.044	2.212	2.202	2.223
SNF	0.129	0.129	0.130	0.132	0.131	0.133	0.166	0.165	0.167	0.197	0.196	0.198	0.235	0.233	0.236	0.279	0.277	0.280	0.323	0.321	0.325

Figure S4: Distribution of total visits [NP, PA, and physician] per patient in 2019



Level	Quantile
100% Max	56 visits
99%	45
95%	30
90%	23
75% Q3	13
50% Median	6
25% Q1	2
10%	0
5%	0
1%	0
0% Min	0

Table S8: Distribution of MD visits per capita by decile in Figure 3 (2019)

Decile	N	Mean	Std Dev	Minimum	Maximum
1	3294	2.7	1.0	0.0	<3.8
2	3295	4.3	0.3	3.8	<4.7
3	3294	5.1	0.2	4.7	<5.4
4	3295	5.7	0.2	5.4	<5.9
5	3294	6.2	0.2	5.9	<6.5
6	3295	6.7	0.2	6.5	<7.0
7	3295	7.3	0.2	7.0	<7.6
8	3294	8.0	0.2	7.6	<8.4
9	3295	9.0	0.3	8.4	<9.6
10	3294	11.6	2.9	9.6	62.9

Table S9: Number of NP and PA visits over time and by setting. Comparison of mean and medians. Data shown in Figures 1 and 2.

Figure 1:

	NP visits		PA visit		Total visits	
	Median number of visits (IQR)	Mean number of visits per patient (SD)	Median number of visits (IQR)	Mean number of visits per patient (SD)	Median number of visits (IQR)	Mean number of visits per patient (SD)
2013	0 (0-0)	0.9 (3.8)	0 (0-0)	0.5 (2.6)	9.0 (4.8-16.6)	9.6 (9.2)
2014	0 (0-0)	0.9 (4.0)	0 (0-0)	0.5 (2.7)	8.8 (4.7-16.2)	9.3 (9.3)
2015	0 (0-0)	1.1 (4.2)	0 (0-0)	0.6 (2.8)	8.9 (4.7-16.4)	9.4 (9.4)
2016	0 (0-0)	1.2 (4.4)	0 (0-0)	0.7 (3.1)	8.9 (4.7-16.4)	9.6 (9.6)
2017	0 (0-2.1)	1.4 (4.8)	0 (0-0)	0.7 (3.1)	8.9 (4.7-16.5)	9.7 (9.7)
2018	0 (0-2.5)	1.5 (5.0)	0 (0-0)	0.8 (3.2)	8.9 (4.7-16.4)	9.8 (9.8)
2019	0 (0-2.8)	1.7 (5.5)	0 (0-0)	0.8 (3.3)	9.0 (4.8-16.5)	9.9 (10.0)

Figure 1:

	NP or PA visits		
	Median	75%	90%
2013	0.0	1.8	6.0
2014	0.0	2.3	6.5
2015	0.0	2.8	7.1
2016	0.0	3.2	7.6
2017	0.0	3.4	8.3
2018	0.0	3.6	8.7
2019	0.0	3.9	9.4

Figure 2:

	Outpatient visits		Nursing facilities visits	
	Median number of visits (IQR)	Mean number of visits per patient (SD)	Median number of visits (IQR)	Mean number of visits per patient (SD)
2013	0 (0-0)	1.2 (4.0)	0 (0-0)	0.13 (2.07)
2014	0 (0-2.0)	1.3 (4.0)	0 (0-0)	0.13 (2.50)
2015	0 (0-2.7)	1.5 (4.2)	0 (0-0)	0.17 (2.95)
2016	0 (0-3.0)	1.7 (4.4)	0 (0-0)	0.20 (3.31)
2017	0 (0-3.3)	1.9 (4.5)	0 (0-0)	0.23 (3.61)
2018	0 (0-3.4)	2.0 (4.5)	0 (0-0)	0.28 (4.02)
2019	0 (0-3.7)	2.2 (4.7)	0 (0-0)	0.32 (4.25)

Table S10: Association between number of NP/PA visits and physician visits per person across zip codes in the US. Zip codes broken down by decile of physician visits (see Table S8 above). Comparison of mean and medians shown in Figure 3.

Decile of physician visits	Median number of visits (IQR)	Mean number of visits per patient (SD)
Decile 1	0.0 (0.0-2.8)	2.41 (2.01)
Decile 2	0.0 (0.0-2.7)	2.77 (1.62)
Decile 3	0.0 (0.0-2.6)	2.80 (1.54)
Decile 4	0.0 (0.0-2.5)	2.90 (1.59)
Decile 5	0.0 (0.0-2.4)	2.85 (1.67)
Decile 6	0.0 (0.0-2.2)	2.73 (1.46)
Decile 7	0.0 (0.0-1.9)	2.65 (1.43)
Decile 8	0.0 (0.0-0.0)	2.59 (1.47)
Decile 9	0.0 (0.0-0.0)	2.44 (1.47)
Decile 10	0.0 (0.0-0.0)	2.40 (2.07)

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