Abstract

Purpose

With radiology practices increasingly employing nonphysician practitioners (NPPs), we aimed to characterize specific NPP clinical roles.

Methods

Linking 2017 to 2019 Medicare data sets, we identified all claims-submitting nurse practitioners and physician assistants (together NPPs) employed by radiologists. NPP-billed services were identified, weighted by work relative value units, and categorized as (1) clinical evaluation and management (E&M), (2) invasive procedures, and (3) noninvasive imaging interpretation. NPP practice patterns were assessed temporally and using frequency analysis.

Results

As the number of radiologist-employed NPPs submitting claims increased 16.3% (from 523 in 2017 to 608 in 2019), their aggregate Medicare fee-for-service work relative value units increased 17.3% (+40.0% for E&M [from 79,540 to 111,337]; +5.6% for procedures [from 179,044 to 189,003]; and +74.0% for imaging [from 5,087 to 8,850]). The number

performing E&M, invasive procedures, and imaging interpretation increased 7.6% (from 329 to 354), 18.3% (from 387 to 458), and 31.8% (from 85 to 112), with 58.2%, 75.3%, and 18.4% billing those services in 2019. Paracentesis and thoracentesis were the most frequently billed invasive procedures. Fluoroscopic swallowing and bone densitometry examinations were the most frequently billed imaging services. By region, NPPs practicing as majority clinical E&M providers were most common in the Midwest (33.5%) and South (33.0%), majority proceduralists in the South (53.1%), and majority image interpreters in the Midwest (50.0%).

Conclusions

As radiology practices employ more NPPs, radiologist-employed NPPs' aggregate services have increased for E&M, invasive procedures, and imaging interpretation. Most radiologist-employed NPPs perform invasive procedures and E&M. Although performed by a small minority, imaging interpretation has shown the largest relative service growth.

Visual Abstract

Introduction

The expanding use of nonphysician practitioners (NPPs) in radiology practice has been a matter of both interest and

contention within the radiology community [,]. Prior Medicare-based studies have reported dramatic national growth in NPP performance of services traditionally rendered by radiologists, such as paracentesis and thoracentesis [ ], central venous access [ ], and imaging interpretation [ ]. But because of the way provider types are coded in Medicare claims, it is unknown from those earlier studies whether those NPPs were employed by radiology or other specialty practices.

Santavicca et al recently reported a 10.5% increase in the number of US radiology practices employing nurse practitioners and physician assistants [ ]. Practices were more likely to employ NPPs when they were larger in size, were located in urban areas, had a larger interventional radiologist composition, and employed younger radiologists. However, the specific clinical roles of those NPPs in their respective practices was not examined.

To further understand the expanding roles of NPPs within the national radiology workforce, we linked national Medicare data sets, building on recently described methods [ ], to characterize clinical services rendered by NPPs employed by radiology practices.

Methods

Because this retrospective HIPAA-compliant study used only

federally designated public use files, it was deemed non–human subjects research by the institutional review board at Emory University and therefore required no formal oversight.

Radiology Practice and Radiologist-Employed NPP Identification

Using publicly available CMS Doctors and Clinicians (formerly Physician Compare) databases, which include all eligible Medicare participating providers from 2017 to 2019, we extracted information for each individual provider in all group practices using reported unique organization identifiers [ ]. In a manner recently described [ ], we defined "radiology practices" as groups in which 100% of affiliated physicians self-identified their primary specialty as diagnostic radiology, interventional radiology, or nuclear medicine (together "radiologists"). We then identified all self-reported nurse practitioners and physician assistants (together, NPPs) affiliated with those practices. As complete data for physician assistants were not reported in Physician Compare files before 2017 (personal communication from Medicare's Quality Payment Program Service Center on October 26, 2021), our analysis focused on years thereafter [ ].

Characterization of NPPs

For each identified NPP in the 50 states and District of

Columbia, we used the CMS Doctors and Clinicians files to compute both the number of NPPs and the number of radiologists employed by their group practices. During the 3-year period, 84 of 865 (9.7%) distinct NPPs were affiliated with two radiology group practices during at least 1 year; for the purposes of this investigation, these NPPs were assigned to the group associated with the larger number of radiologists.

CMS National Provider Identifiers were used to obtain information regarding each NPPs' Medicare billed services from the separate publicly available CMS Physician and Other Suppliers Public Use Files (POSPUF). POSPUF contains provider-service level counts of all Part B fee-for-service Medicare claims billed more than 10 times annually [ ]. Annual POSPUF data sets from 2017, 2018, and 2019 were used to extract self-reported provider type, self-reported gender (reported by Medicare in a binary fashion as male or female), billing location (state, zip code), Rural-Urban Commuting Area code, and line service count. NPPs affiliated with radiology practices who did not submit claims to Medicare were absent in POSPUF and thus excluded from our analysis.

Additionally linking CMS Physician Fee Schedule files [ ] to annual Medicare Part B claims data using Current Procedural Terminology (CPT) codes, we calculated the total relative

clinical work effort attributed to individual reported services for each claims-submitting NPP as the product of line service count and corresponding 2021 work relative value units (wRVUs). NPPs were each assigned to a US Census region based on their reported state. Each NPP's billing location was further characterized as urban or rural using the Census tract-based Rural-Urban Commuting Area classification scheme, with urban defined as Rural-Urban Commuting Area codes corresponding to a metropolitan area core or metropolitan area with high commuting [ ].

Medicare Service Classification

Reported Medicare services billed by all included NPPs were categorized as follows:

•

Clinical evaluation and management (E&M): any service with an E&M family CPT code between 99201 and 99499 (34.6% of total wRVUs);

•

Invasive imaging-guided procedures: any service with a surgical family CPT code between 10000-69999 or a Neiman Imaging Types of Service invasive CPT code [ ] (61.9% of total wRVUs);

•

Noninvasive diagnostic imaging: any service with a Neiman Imaging Types of Service noninvasive diagnostic imaging CPT code [ ] (2.1% of total wRVUs);

•

Other services: all other remaining services (1.3% of total wRVUs). Since most of these services were incidental to other services (eg, peripheral intravenous access or injectables during procedures) or unrelated to typical radiology care (eg, vaccine administrations that might have been provided as a convenience service to practice members), they were excluded from the remainder of the analysis.

For each NPP, wRVUs were aggregated for all three service categories to compute the percentage of total clinical work effort attributable to each service category. In a manner similar to that described by Rosenkrantz et al for radiologist subspecialty determination [,], each NPP's majority wRVU focus was determined when greater than 50% of their total wRVUs were attributable to a specific service category.

Descriptive and Statistical Analyses

We calculated and illustrated the total and percentage of

national annual Medicare fee-for-service wRVUs billed by NPPs working in radiology practices, stratified by service category. For each reported service, we then calculated the annual number of unique rendering NPPs in radiology practices, stratified by individual NPP majority work effort category (measured in wRVUs). To help characterize the work profile distributions of NPPs in radiology practices, we identified the aggregate 10 most billed services in 2019 for each defined service category. For each reported service we calculated (1) the percentage of overall service category specific services occupied by that service and (2) the percentage of all radiology NPPs who billed that service.

To inform discussions about the geographic dispersion of these providers, we generated a zip code–level heat map for 2019 illustrating the number of NPPs in radiology practices overlaid on population density. For enhanced interpretability of NPP counts and 2010 Census population statistics [ ] obtained at the five-digit geographic zip code level, we used geographic coordinates from the GeoNames database [ ] to calculate the centroid of, and report at, the three-digit zip code level for data visualization. These metrics were additionally aggregated to combined statistical areas using a publicly available crosswalk file [ ].

To further characterize radiologist-employed NPPs based on their work majority wRVU effort profile distributions (clinical

E&M, invasive procedures, and imaging interpretation), we conducted a frequency analysis of NPPs by practice characteristics (number of NPPs in group practice, number of radiologists in group practice, total services billed to Medicare), demographics (years of experience since training, gender, provider type), and geography (census region, practice location. For each of these factors, we calculated means or proportions in each of the three majority wRVU-focus service categories in 2017 and 2019. Within each majority wRVU-focus service category, two-sample *t* tests were used to compare means of continuous variables between 2017 and 2019. χ^2 Tests with Yates' continuity correction were used to compare proportions of binary categorical variables and distributions of multinomial categorical variables (region) between 2017 and 2019.

Initial database management and analysis was performed using SAS (version 9.4, SAS Institute Inc, Cary, North Carolina). Graphical visualization was prepared in the R programming environment (version 4.1.2, R Foundation for Statistical Computing, Vienna, Austria). Subsequent geographical and frequency analyses were conducted using Tableau (version 2018.1, Tableau Software, Mountain View, California) and Stata Statistical Software (Release 16.1, StataCorp LLC, College Station, Texas), respectively. All tests of significance were evaluated as two-sided tests with $\alpha = 0.5$.

Results

Descriptive Analyses of Radiologist-Employed NPPs Between 2017 and 2019

Between 2017 and 2019, the number of NPPs in radiology-only practices who submitted identifiable claims to Medicare increased from 523 to 608 (+16.3%). These claims-submitting NPPs were affiliated with 196 practices in 2017 and 224 in 2019, representing 6,107 and 6,930 radiologists, respectively.

In aggregate (Fig. 1), radiologist-employed NPP total Medicare fee-for-service billed wRVUs increased from 263,671 in 2017 to 309,190 in 2019 (+17.3%). Their total national clinical E&M wRVUs increased from 79,540 to 111,337 (+40.0%), invasive procedural wRVUs increased from 179,044 to 189,003 (+5.6%), and noninvasive imaging interpretative service wRVUs increased from 5,087 to 8,850 (+74.0%).

Fig. 1

Total national annual Medicare fee-for-service work relative value unit (wRVUs) billed by all nurse practitioners and physician assistants working in radiology practices, grouped by service category. Percentages of total national annual total wRVUs are listed in parentheses. E&M = evaluation and management.

Across all 3 years, the number of NPPs with a majority work

effort in clinical E&M services increased 9.7% from 185 (35.4% of all) to 203 (33.4%) (Fig. 2); these NPPs were associated with 113 radiology practices in 2017 and 116 in 2019. The number performing any reported E&M services increased 7.6% from 329 (62.9% of all NPPs) to 354 (58.2%); these NPPs were associated with 155 radiology practices in 2017 and 170 in 2019.

Fig. 2

Annual numbers of unique nonphysician practitioners employed by radiology practices, stratified by individual nonphysician practitioner majority work effort category (measured in work relative value units) as well as type of nonphysician practitioner (ie, nurse practitioner versus physician assistant). E&M = evaluation and management; wRVU, work relative value unit.

Also increasing over this time, most radiologist-employed NPPs devoted the majority of their work effort to invasive procedures (Fig. 2). The number working as majority proceduralists increased 17.5% from 326 (62.3% of all NPPs) in 2017 to 382 (63.0%) in 2019; these NPPs were associated with 132 radiology practices in 2017 and 116 in 2019. The number performing any reported invasive procedural services increased 18.3% from 387 (74.0% of all NPPs) in 2017 to 458 (75.3%) in 2019; these NPPs were associated with 149 radiology practices in 2017 and 181 in 2019.

Between 2017 and 2019, the number of radiologist-employed NPPs who devoted the majority of their work

effort to imaging interpretation increased 83.3% from 12 (2.3%) to 22 (3.6%) (Fig. 2); these NPPs were associated with 7 radiology practices in 2017 and 14 in 2019. The number performing any reported imaging interpretation services increased 31.8% from 85 (16.3% of all NPPs) to 112 (18.4%); these NPPs were associated with 41 radiology practices in 2017 and 66 in 2019.

As also illustrated in Figure 2 , most radiologist-employed nurse practitioners worked predominantly as clinical E&M service providers (65.8% in 2017 and 58.8% in 2019). A larger majority of physician assistants worked predominantly as proceduralists (73.7% in 2017 and 73.2% in 2019). The number of physician assistants (10 in 2017 and 20 in 2019) working predominantly as image interpreters increased but remained low; the number of nurse practitioners (2 in both 2017 and 2019) working predominantly as image interpreters was unchanged.

Clinical E&M

A total of 69,034 clinical E&M services were billed by 354 radiologist-employed NPPs in 2019. Of these, 29,338 (42.5%) were rendered in the inpatient setting, 35,262 (51.1%) in the outpatient setting, 1,994 (2.9%) in the emergency department, and 2,440 (3.5%) in all other sites (eg, nursing homes). The 10 most frequently billed CPT codes, which together account for 60,510 (87.6%) of all

clinical E&M services billed by radiology NPPs, are detailed in Table 1 .

Table 1

Top 10 most frequently billed services by radiologist-employed NPPs in 2019, categorized by service type

CPT Code	Service	Service Counts *	% of NPPs	Unique Radiology NPPs	% Ra
Clinical evaluation and management services					
99213	Established outpatient visit (15 min)	14,946	21.6	168	27
99232	Established inpatient visit (25 min)	13,797	20.0	138	22
99214	Established patient outpatient visit (25 min)	9,982	14.5	125	20
99231	Established inpatient visit (15 min)	8,822	12.8	130	21
99203	New outpatient visit (30 min)	3,572	5.2	80	13

99204	New outpatient visit (45 min)	2,555	3.7	60	9.
99222	Initial inpatient visit (30 min)	2,470	3.6	48	7.9
99212	Established outpatient visit (10 min)	1,531	2.2	45	7.4
99221	Initial inpatient visit (50 min)	1,469	2.1	50	8.
99233	Established inpatient visit (35 min)	1,366	2.0	37	6.
Invasive imaging-guided procedures					
49083	Paracentesis with imaging guidance	23,065	19.9	354	58
32555	Thoracentesis with imaging guidance	18,098	15.6	333	54
76937	Ultrasound guidance for vascular access	9,720	8.4	179	29
	Fluoroscopic guidance				

77001	central venous access	9,357	8.1	174	28
36573	Peripherally inserted central venous catheter placement	7,899	6.8	159	26
77002	Fluoroscopic guidance for needle placement	4,592	4.0	144	23
20610	Large joint arthrocentesis	3,584	3.1	113	18
77003	Fluoroscopic guidance for spinal needle placement	3,068	2.7	130	21
36558	Central venous catheter placement	2,972	2.6	91	15
10005	Fine needle aspiration	2,835	2.5	99	16
Noninvasive diagnostic imaging services					
77080	DEXA scan	13,187	50.1	33	5.
74230	Swallowing function	5,098	19.4	53	8.

	examination				
77085	DEXA scan, with vertebral fracture assessment	3,110	11.8	14	2.
74220	Single contrast esophagram	1,263	4.8	35	5.
71045	X-ray of chest, 1 view	348	1.3	7	1.
93971	Extremity venous duplex, limited or unilateral	244	0.9	8	1.
76604	Ultrasound of chest	222	0.8	8	1.
71046	X-ray of chest, 2 views	207	0.8	4	0.
93970	Extremity venous duplex, complete bilateral	197	0.7	6	1.
76705	Ultrasound of abdomen, limited	179	0.7	10	1.

CPT = Current Procedural Terminology; DEXA = dual energy x-ray absorptiometry; NPP = nonphysician practitioner.

∗ Counts reflect all services rendered nationally to Medicare fee-for-service beneficiaries by NPPs in radiology practices.

Invasive Procedures

A total of 115,645 services representing 127 unique CPT codes were billed by 458 radiologist-employed NPPs in 2019. Paracentesis (23,065; 19.9% of all) and thoracentesis (18,098; 15.6% of all) together accounted for over one-third of all invasive procedures. A total of 12 venous access codes accounted for 30,556 services, together representing 26.4% of all invasive procedures performed by NPPs in radiology practices. The 10 most frequently billed CPT codes, which together account for 85,190 (73.7%) of invasive procedural services billed by radiology NPPs, are detailed in Table 1 .

Noninvasive Diagnostic Imaging

A total of 26,313 noninvasive diagnostic imaging services were billed by 112 radiologist-employed NPPs in 2019. Of the 50 unique CPT codes, three (77080, 77085, and 77081) for bone densitometry (“DEXA”) accounted for 16,433 (62.5%) of all services and two (74320 and 74220) for swallowing studies accounted for 6,361 (24.2%). Twenty unique radiographic CPT codes accounted for 3,028 (11.5%). Of these, one- and two-view chest radiography were most common (555 total counts), together representing 2.1% of all radiologist-employed NPP-billed imaging services. The 10

most frequently billed unique CPT codes, which together account for 24,055 (91.4%) of noninvasive diagnostic imaging services billed by radiology NPPs, are detailed in Table 1 .

A large majority of NPPs employed by radiology practices were based in and around counties with some of the highest populations and population densities in the country (Fig. 3). The metropolitan areas with the highest counts of NPPs in 2019 were Charlotte-Concord, North Carolina–South Carolina (92 NPPs); Atlanta-Athens–Sandy Springs, Georgia (72); Grand Rapids, Wyoming–Muskegon, Michigan (50); New York–Newark, New York–New Jersey–Connecticut-Pennsylvania (45); and Chicago-Naperville, Illinois-Indiana-Wisconsin (40).

Fig. 3

Distribution of nonphysician practitioners (NPPs) in radiology practices in 2019 overlaid upon US population density (1,000 per square mile) at the three-digit zip code level, illustrating that radiologist-employed NPPs are largely located in higher (rather than lower) population density regions.

Frequency Analysis by NPP Majority wRVU Effort

As outlined in Table 2 , for the 203 NPPs in 2019 with a majority of their work effort in clinical E&M, the average number of group NPP and radiologists were 5.5 and 38.0, respectively. These NPPs had on average 8.9 years of

experience since training and billed a mean 309.1 total Medicare services. Of these 203 NPPs, 78.3% self-reported gender as female (versus 21.7% male); 54.2% were defined by CMS as nurse practitioners and 45.8% as physician assistants. Regional distribution of these NPPs ranged from 11.8% in the Northeast to 33.5% in the Midwest, with 10.3% practicing in rural areas.

Table 2

Practice, professional, personal, and geographic characteristics of radiologist-employed NPPs by majority wRVU focus between 2017 and 2019

Characteristics	Majority Effort in Clinical E&M			Majority Effort in Invasive Procedures		
	2017 (n = 185)	2019 (n = 203)	*P*	2017 (n = 326)	2019 (n = 382)	*P*
Group practice (mean)						
Number of group non-physician practitioners	5.9	5.5	.534	7.1	7.0	.878
Number of group radiologists	47.8	38.0	.038	52.3	53.5	.728
NPP (mean)						

Experience (years)	9.9	8.9	.168	10.3	10.7	.461
Services billed to Medicare (hundreds)	303.5	309.1	.886	441.4	357.4	.003
Self-reported gender (proportion), %			.553			.925
Female	75.3	78.3		61.4	62.0	
Male	24.7	21.7		38.7	38.0	
Provider type (proportion), %			.764			.094
Nurse practitioner	52.1	54.2		14.7	19.8	
Physician assistant	47.9	45.8		85.3	80.2	
Region (proportion), %			<.001			<.001
Midwest	28.0	33.5		14.4	19.8	
Northeast	15.6	11.8		14.1	14.8	
South	35.0	33.0		54.6	53.1	
West	21.5	21.7		16.9	12.2	
Practice location (proportion), %			.891			.839
Rural	11.3	10.3		1.8	2.3	
Urban	88.7	89.7		98.2	97.7	

P -values reflect two-sample *t* tests for means of continuous

variables and χ^2 tests for proportions of binary categorical variables and distributions of multinomial categorical variables. E&M = evaluation and management services; NPP = nonphysician practitioner; wRVU = work relative value unit.

For the 382 NPPs in 2019 with a majority of their work effort in invasive procedures, the average number of group NPPs and radiologists were 7.0 and 53.5, respectively. These NPPs had on average 10.7 years of experience since training and billed a mean of 357.4 total Medicare services. Of these 382 NPPs, 62.0% self-reported gender as female (versus 38.0% male); 19.8% were defined by CMS as nurse practitioners and 80.2% as physician assistants. Regional distribution of these NPPs ranged from 12.2% in the West to 53.1% in the South, with 2.3% practicing in rural areas.

For the 22 NPPs in 2019 with a majority of their word effort in imaging interpretation, the average number of group NPPs and radiologists were 9.7 and 86.0, respectively. These NPPs had on average 14.0 years of experience since training and billed a mean of 667.5 total Medicare services. Of these 22 NPPs, 45.5% self-reported gender as female (versus 54.6% male); 9.1% were defined by CMS as nurse practitioners and 91.0% as physician assistants. Regional distribution of these NPPs ranged from 18.2% in the West to 50.0% in the South, with 9.1% practicing in rural areas.

Although the mean size of groups employing NPP majority proceduralists and imaging interpreters did not significantly change from 2017 to 2019, the number of affiliated group NPPs and radiologists decreased on average for NPPs focused in clinical E&M (mean number of radiologists 47.8 in 2017 and 38.0 in 2019, $P = .038$). The mean number of total billed Medicare services decreased from 441.4 in 2017 to 357.4 in 2019 for majority effort proceduralists ($P = .003$) but did not significantly change for majority effort E&M providers or image interpreters. Additional temporal characteristics are detailed in Table 2 .

Discussion

Linking NPPs to their physician groups using distinct Medicare data sets, we identified NPPs employed by radiology practices who billed services for Medicare fee-for-service beneficiaries between 2017 and 2019 and then categorized and characterized those services. We found that as the number of radiology practices employing NPPs has increased, their national aggregate services increased commensurately for invasive procedures, E&M, and imaging interpretation alike. Over all 3 years, a majority of radiologist-employed NPPs performed invasive imaging-guided procedures and E&M services. Although only a small minority of radiologist-employed NPPs billed for imaging interpretation, relative growth for imaging interpretation was

greatest across all three categories.

Our findings overall are concordant with those described in a number of Medicare-based studies examining services rendered by NPPs in areas traditionally performed by radiologists. Prior studies have reported substantial increases in the numbers of NPP-billed venous access procedures [ ], paracentesis and thoracentesis procedures [ ], and a variety of other nonvascular invasive procedures such as biopsies and drainages [ ]. Many of these reflect procedures performed more commonly by general (rather than interventional) radiologists [ ], highlighting the need for radiology practices of all sizes to provide a diverse array of services to their patients [ ].

The need for interventional radiology practices to expand and support their clinical services has been highlighted in previous reports describing increases in E&M services rendered by interventional radiologists [,]. Expansion of E&M services has been associated with increases in both the volume and complexity of interventional radiology procedures [ ]. NPPs have been described as part of a team-based approach, within appropriate regulatory confines, to grow an interventional radiology practice's clinical presence [,]. We believe that the observed growth of E&M services rendered by radiologist-employed NPPs, particularly in light of increased employment of NPPs by radiology practices

with larger interventional presences [ ], reflects ongoing adoption of such team-based interventional radiology care.

The number of imaging interpretation services rendered by radiologist-employed NPPs grew considerably during our short observation window. Makeeva et al previously reported even more dramatic relative growth (+14,711%) in the volume of imaging services rendered by NPPs nationwide between 2004 and 2015, but they were unable to map those NPPs to their specialty groups (eg, radiology versus nonradiology practices) [ ]. With other Medicare data sets since 2017 fully including nurse practitioners and physician assistants, such linking is now possible. In contrast to NPPs more broadly providing a variety of radiography and fluoroscopy services, we found that 86.7% of all imaging interpretation services billed by radiologist-employed NPPs fell into two narrow groups (bone densitometry and swallowing studies), which seem qualitatively different than most traditional diagnostic imaging performed by most radiologists. Both are examinations with potentially low radiologist interest and ones already being assumed by other specialties (ie, bone densitometry by endocrinologists and swallowing studies by speech pathologists). As such, radiologist-employed NPPs are performing services that the specialty may otherwise be at risk of dispossession entirely to nonradiologists, thus keeping these examinations within the specialty. Radiology practices that use NPPs in this manner, however, should be

aware of ACR policy that specifically indicates that "rendering interpretations of medical imaging studies (preliminary, final, or otherwise) is beyond the scope of practice and is not the intended role of non-physician members of the healthcare team" [ ].

As already noted, the roles of NPPs in radiology practices are controversial [,] and a matter of ongoing professional society policy debate [ ]. Our aggregate claims-based analysis does not allow us to study outcomes of services rendered by NPPs versus those rendered by radiologists nor opine on whether the trends and characteristics we describe are either good or bad for the specialty or its patients. Such questions will require further study and analysis. Nonetheless, we believe that our findings help characterize the radiology workforce and marketplace in a manner that can inform ongoing policy debates. Future work, we believe, could explore some of the characteristics we identified to study how NPPs may be helping expand patient access (both geographically and with regard to specific service lines).

As with any analysis based on administrative data from CMS, ours has limitations. Because of privacy concerns, CMS does not report service fields with 10 or fewer counts, and thus we have likely excluded services rendered by some NPPs who performed very few services. Additionally, we were unable to

identify whether NPP-billed services were performed completely independently by that NPP or with some degree of radiologist oversight. We also acknowledge that our results may not be generalizable to nurse practitioners and physician assistants working with radiologists in multispecialty groups or to other nonphysician providers such as radiologist assistants. Finally, given the small number of providers with a majority of their work effort in noninvasive diagnostic imaging and captured in our controlled sample of radiology-only practices, advanced regression-based modeling would be too underpowered to facilitate majority effort characterization.

Conclusion

In conclusion, as radiology practices have increasingly employed NPPs, services performed by those NPPs have increased for E&M, invasive procedures, and imaging interpretation. Although most radiologist-employed NPPs perform E&M and invasive procedures, a small but increasing number are interpreting imaging. Although such growth could increase patient access to radiology services, the implications on the radiologist workforce and patient outcomes are unknown and merit further investigation.

Take-Home Points

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As the number of radiologist-employed NPPs increased 16.3% between 2017 and 2019, their associated national Medicare wRVUs increased 17.3% overall.

▪

National radiologist-employed NPP wRVUs increased 40.0% for E&M, 5.6% for invasive procedures, and 74.0% for imaging interpretation.

▪

A majority of radiologist-employed NPPs perform invasive procedures and E&M (75.3% and 58.2% in 2019, respectively).

▪

Of all three service categories, relative growth in the number of radiologist-employed NPPs performing a related service has been largest (+31.8%) in imaging interpretation (18.4% of all radiology NPPs in 2019).

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References

1. Jha S.: Navigating the paradox of scarcity—the case for physician extenders. J Am Coll Radiol JACR 2021; 18: pp. 148-150.

2. Ortiz D.A., Cregan K.M., Luh J.Y., Kattapuram T.M.: Navigating the paradox of scarcity—the case for radiologist-driven care. J Am Coll Radiol 2021; 18: pp. 151-153.

3. Duszak R., Chatterjee A.R., Schneider D.A.: National fluid shifts: fifteen-year trends in paracentesis and thoracentesis procedures. J Am Coll Radiol 2010; 7: pp. 859-864.

4. Duszak R., Bilal N., Picus D., Hughes D.R., Xu B.J.: Central venous access: evolving roles of radiology and other specialties nationally over two decades. J Am Coll Radiol 2013; 10: pp. 603-612.

5. Makeeva V., Hawkins C.M., Rosenkrantz A.B., Hughes D.R., Chaves L., Duszak R.: Diagnostic imaging examinations interpreted by nurse practitioners and physician assistants: a national and state-level Medicare claims analysis. AJR Am J Roentgenol 2019; 213: pp. 992-997.

6. Santavicca S., Hughes D.R., Rosenkrantz A.B., Rubin E.,

Duszak R.: Radiology practices employing nurse practitioners and physician assistants: characteristics and trends from 2017 through 2019. J Am Coll Radiol 2022; 19: pp. 746-753.

12. Rosenkrantz A.B., Wang W., Hughes D.R., Ginocchio L.A., Rosman D.A., Duszak R.: Academic radiologist subspecialty identification using a novel claims-based classification system. AJR Am J Roentgenol 2017; 208: pp. 1249-1255.

13. Rosenkrantz A.B., Wang W., Bodapati S., Hughes D.R., Duszak R.: Private practice radiologist subspecialty classification using Medicare claims. J Am Coll Radiol 2017; 14: pp. 1419-1425.

17. Duszak R., Walls D.G., Wang J.M., et. al.: Expanding roles of nurse practitioners and physician assistants as providers of nonvascular invasive radiology procedures. J Am Coll Radiol 2015; 12: pp. 284-289.

18. Rosenkrantz A.B., Friedberg E.B., Prologo J.D., Everett C., Duszak R.: Generalist versus subspecialist workforce characteristics of invasive procedures performed by radiologists. Radiology 2018; 289: pp. 140-147.

19. Youmans D.C., Duszak R., Rosenkrantz A.B., Fleishon H.B., Friedberg E.B., Rodgers D.A.: Value of the new general radiologist in private practice. J Am Coll Radiol 2021; 18: pp.

786-788.

20. Duszak R., Mabry M.R.: Clinical services in interventional radiology: results from the national Medicare database and a Society of Interventional Radiology membership survey. J Vasc Interv Radiol 2003; 14: pp. 75-81.

21. Duszak R., Borst R.F.: Clinical services by interventional radiologists: perspectives from Medicare claims over 15 years. J Am Coll Radiol 2010; 7: pp. 931-936.

22. Kwan S.W., Valji K.: Interventional radiologists' involvement in evaluation and management services and association with practice characteristics. J Vasc Interv Radiol 2012; 23: pp. 887-892.

23. Hawkins C.M., Bowen M.A., Gilliland C.A., Walls D.G., Duszak R.: The impact of nonphysician providers on diagnostic and interventional radiology practices: regulatory, billing, and compliance perspectives. J Am Coll Radiol 2015; 12: pp. 776-781.

24. Hawkins C.M.: Rules and regulations relating to roles of nonphysician providers in radiology practices-erratum. Radiographics 2019; 39: pp. 912.