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Comparison of Number and Geographic Distribution of Pediatric Subspecialists and Patient Proximity to Specialized Care in the US Between 2003 and 2019

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Supplemental content

IMPORTANCE Geographic proximity to a pediatric subspecialist is a key factor in obtaining specialized care. However, comparative data regarding the number of pediatric subspecialists, distribution of subspecialists, and patient proximity to subspecialists in the United States between 2003 and 2019 have not been explored; the last known national analysis was published in 2006 and used data from 2003.

OBJECTIVE To compare the number and distribution of pediatric subspecialists and patient proximity to pediatric subspecialists in the United States between 2003 and 2019 and to assess whether the increase in the number of pediatric subspecialists is associated with improvements in patient proximity to specialized care and the geographic distribution of pediatric subspecialists.

DESIGN, SETTING, AND PARTICIPANTS This national repeated cross-sectional study used data from the American Board of Pediatrics to examine the overall change in the number of subspecialists for 20 pediatric subspecialties between 2003 and 2019. The study included 24 375 pediatric subspecialists who were 70 years or younger, had active certification from the American Board of Pediatrics as of June 2019, and had addresses in the United States. Subspecialists' addresses were linked by zip code to child population data to evaluate the geographic distribution of subspecialists, the population-weighted averages for service areas, and the straight-line distances to subspecialists. Descriptive statistics and maps were used to examine patient proximity to subspecialists and regional subspecialist distribution and dispersion by hospital referral region. Subspecialist-to-child population ratios per 100 000 children, changes over time, and coefficients of variation were calculated to further elucidate subspecialist distribution. Data were collected in June 2019 and analyzed from July 8, 2019, to December 17, 2019.

MAIN OUTCOMES AND MEASURES Values from 2019 were compared with data from 2003 for mean straight-line distance in miles from patients to subspecialists, by subspecialty; percentage of children younger than 18 years living at specific distance ranges; subspecialist-to-child population ratios across hospital referral regions; and coefficients of variation for population ratios.

RESULTS Among 24 375 pediatric subspecialists 70 years and younger, 23 436 subspecialists were certified in 1 subspecialty, and 939 subspecialists were certified in more than 1 subspecialty. The number of certified pediatric subspecialists in the United States increased by 76.8% between 2003 and 2019, with increases varying across subspecialties. The estimated means for travel distances decreased among all subspecialties; however, depending on the subspecialty, an estimated 1 million to 39 million children (2%-53%) resided 80 miles or more from a subspecialist. An analysis across hospital referral regions indicated increased subspecialist-to-child ratios and an increased number of regions with a subspecialist but continued wide variation across regions for most subspecialties. Eleven subspecialties had 1 or fewer subspecialists per 100 000 children across hospital referral regions.

CONCLUSIONS AND RELEVANCE Although patient proximity to pediatric subspecialty care has improved nationally, substantial distribution gaps among specific subspecialties remain. Long-term solutions that encourage movement of subspecialists to underserved locations or that extend the practice of current subspecialties may warrant consideration, particularly among subspecialties with a limited number of practitioners.

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The number of US-based third-year pediatric subspecialist fellows has nearly doubled, from 678 to 1310 fellows, in the last 15 years, while the number of US children younger than 18 years has remained relatively constant at approximately 73 to 74 million children.[1] Yet a perceived shortage of subspecialists across numerous pediatric subspecialties remains.[2,3] Results from a 2017 insurance marketplace analysis indicated that, on average, 65.9% of the analyzed Patient Protection and Affordable Care Act insurance plans provided limited access or no access to pediatric subspecialists, which was substantially higher than the 34.9% of plans providing limited or no access to adult-trained subspecialists.[4] Surveys from 2012 and 2017 described long wait times for care and multiple vacancies in practitioner positions in several pediatric subspecialties.[2] Surveys of parents from 2009 to 2010 identified distance as a barrier to accessing care; those residing at great distances from subspecialists listed geographic and transportation issues as the primary barriers to their children's care. The same study found that increased distance was frequently associated with decreases in health care service use and the perceived need for care.[5]

Studies from 2006 and 2009 examined the association between the number of pediatric subspecialists and the geographic distribution of subspecialists over time by analyzing patient geographic proximity (ie, estimated driving distance to visit a pediatric subspecialist) and the national distribution of pediatric subspecialists.[6,7] Results indicated wide variation in each subspecialty's national distribution and mean patient proximity; notably, the increase in the number of subspecialists was not necessarily associated with a wider distribution of subspecialists. A 2016 regional study in Pennsylvania indicated that greater driving distances to care were associated with an increased likelihood that a child would visit an adult-trained subspecialist rather than a pediatric subspecialist; this adult-trained subspecialist may be less likely to understand the differences in pediatric disease presentation or to have up-to-date knowledge of evidence-based pediatric care.[8]

In light of these findings, this study sought to replicate a 2006 study by Mayer[6] that analyzed the estimated distances to pediatric subspecialists using data collected in 2003. We aimed to describe changes in the number of subspecialists during the past 16 years and their association with patient proximity to care and the overall geographic distribution of subspecialists.

Key Points

Question Is the increase in the number of pediatric subspecialists between 2003 and 2019 associated with improvements in patient proximity to specialized care and the national geographic distribution of pediatric subspecialists?

Findings In this cross-sectional study of 24 375 pediatric subspecialists across 306 hospital referral regions, the increase in the number of pediatric subspecialists between 2003 and 2019 was associated with improvements in patient proximity to a pediatric subspecialist among all of the subspecialties analyzed; however, depending on the subspecialty, 1 million to 39 million children (2%-53%) resided 80 miles or more from a subspecialist. When measured across hospital referral regions, 11 pediatric subspecialties had mean ratios of 1 or fewer subspecialists per 100 000 children.

Meaning The increase in the number of pediatric subspecialists was associated with improvements in the geographic distribution of all pediatric subspecialists; however, among several subspecialties, children residing in some geographic areas had limited or no access to specialized care within a reasonable driving distance.

Methods

Number of Pediatric Subspecialists

The 2006 analysis examined 16 pediatric subspecialties[6]; the current analysis includes 20 pediatric subspecialties, 14 of which are certified by the American Board of Pediatrics (ABP) and 6 of which are certified jointly with other boards (**Table 1**). This analysis includes 5 new subspecialties (child abuse, hospice and palliative medicine, medical toxicology, sleep medicine, and transplant hepatology) that were introduced after 2006. The neurodevelopmental disabilities subspecialty was not included because it has not been certified through the ABP since 2007.[8] In addition, certification in pediatric hospital medicine was first offered in 2019 and was therefore not included in the analysis. The addition of 5 new subspecialties and the exclusion of the neurodevelopmental disabilities subspecialty limited direct comparisons of these subspecialties with the 2003 data. Certification data from the ABP and the American Board of Medical Specialties were obtained in June 2019 and included approximately 24 375 pediatric subspecialists with active certifications as of that date. A total of 939 subspecialists were board-certified in more than 1 subspecialty; in such cases, each active certification was counted separately, as most additional certifications were jointly administered by other boards.[9] This study was approved by the institutional review board of the ABP and deemed exempt from informed consent because it was a secondary analysis of operational data.

As in the 2006 analysis, we used current address data from the ABP to approximate the practice location of each certified subspecialist 70 years and younger. The cutoff age of 70 years was used to approximate retirement age and to limit those permanently certified (ie, certified before May 1989) in their field who may not have been actively practicing. Data were accessed from the ABP certification database in June 2019, with the exception of data from the American Board of Allergy and Immunology, which were obtained from the American Board of Medical Specialties. The latest addresses on file were taken from the ABP database rather than the American Medical Association Masterfile because of reported issues with location and specialty accuracy in the latter.[10] Additional details about data sources and methods are available in the eTable in the Supplement.

Table 1. Distance to a Certified Pediatric Subspecialist by Population-Weighted US Zip Code, 2003 vs 2019

Subspecialty	Year certification first offered	Pediatric subspecialists, No.			Distance to nearest pediatric subspecialist, miles[a]				
					2003		2019		
		2003	2019	Change from 2003 to 2019, No. (%)	Mean	75th-95th percentile	Mean	75th-95th percentile	Change from 2003 to 2019, %
ABP certifications									
Adolescent medicine[b]	1994	396	501	105 (26.5)	42	54-138	35.8	49-126	−14.8
Child abuse pediatrics	2009	NA	317	NA	NA	NA	35.0	45-119	NA
Developmental-behavioral pediatrics	2002	296	699	403 (136.1)	44	55-145	26.7	35-95	−39.4
Neonatal-perinatal medicine	1975	3588	4959	1371 (38.2)	15	17-58	11.8	14-48	−21.1
Pediatric cardiology	1961	1503	2558	1055 (70.2)	22	28-84	17.3	21-65	−21.2
Pediatric critical care medicine	1987	1013	2453	1440 (142.2)	26	33-90	19.0	23-73	−26.8
Pediatric emergency medicine[b]	1992	1075	2386	1311 (122.0)	35	44-122	24.4	29-99	−30.3
Pediatric endocrinology	1978	889	1334	445 (50.1)	26	35-94	20.4	26-78	−21.6
Pediatric gastroenterology	1990	712	1488	776 (109.0)	32	38-107	21.2	27-81	−33.8
Pediatric hematology-oncology	1974	1553	2469	916 (59.0)	26	29-89	19.0	24-75	−27.0
Pediatric infectious diseases	1994	838	1167	329 (39.3)	31	38-101	23.9	30-86	−22.8
Pediatric nephrology	1974	530	644	114 (21.5)	36	46-140	29.4	36-114	−18.4
Pediatric pulmonology	1986	627	1073	446 (71.1)	31	38-107	25.6	31-95	−17.4
Pediatric rheumatology	1992	173	387	214 (123.7)	60	75-222	42.8	55-154	−28.7
Joint board certifications									
Allergy and immunology[c]	1971	514	967	453 (88.1)	32	35-109	22.7	27-86	−28.8
Hospice and palliative medicine[b]	2008	NA	301	NA	NA	NA	35.5	47-120	NA
Medical toxicology[b]	1994	NA	31	NA	NA	NA	125.3	196-358	NA
Sleep medicine[b]	2007	NA	282	NA	NA	NA	39.7	95-223	NA
Sports medicine[b]	1993	82	251	169 (206.1)	78	100-241	39.7	51-160	−49.1
Transplant hepatology[b]	2006	NA	108	NA	NA	NA	65.2	52-150	NA
Total certifications	NA	13 789	24 375	10 586 (76.8)	NA	NA	NA	NA	NA

Abbreviations: ABP, American Board of Pediatrics; NA, not applicable or not available.

[a] Analyses for mean and 75th and 95th percentiles used zip codes in the continental United States only.

[b] Certification was offered by 1 or more boards within the American Board of Medical Specialties. Analysis included only subspecialists certified by the ABP.

[c] Analysis included only physicians who were currently certified in general pediatrics and allergy/immunology.

Proximity to Pediatric Subspecialists

Child-to-subspecialist distances were calculated using zip code tabulation area (ZCTA) centroids. As in the 2006 study, straight-line (geodesic) distances between each ZCTA, and not actual driving routes, were used to estimate driving distance.[11] To analyze patient distance to a subspecialist, a matrix of all ZCTA-to-ZCTA distances in the United States was created using the 2016 US Gazetteer database (US Census Bureau).[12] A recursive query identified the closest subspecialists for every ZCTA and reported the distance between each patient-subspecialist pairing (in which the term *patient* denotes a ZCTA that represents a group of patients), assigning a value of 0 miles if the patient and subspecialists were in the same ZCTA. Alaska, Hawaii, and Puerto Rico were excluded from estimates because of the extreme variance in distances associated with those jurisdictions. Subspecialty-specific mean and percentile distance estimates (Table 1) were weighted by the number of children 17 years and younger in each ZCTA to account for population differences by ZCTA; child population data estimates were drawn from the 2017 American Community Survey.[13]

Driving distance was categorized for comparisons using the 2006 categories (≤10 miles, 11-20 miles, 21-40 miles, 41-80 miles, and >80 miles). The estimated numbers of US children in these geographic bands were calculated by aggregating the child population of each ZCTA within a distance category. Driving distances were plotted on a map of US counties.

Distribution and Subspecialist-to-Child Ratio

As with the 2006 analysis, no defined geographic spatial distribution or regional market area had been developed specifically for pediatric subspecialty care, with the exception of neonatal intensive care regions, which were developed solely for neonatal-perinatal pediatricians. In the absence of defined pediatric market areas, this analysis used hospital referral regions[6] as proxies for market areas with pediatric subspecialized care. Hospital referral regions were developed by using Medicare data to analyze the locations in which major cardiovascular procedures were performed relative to patient zip code locations,[14] resulting in 306 tertiary medical care market areas.

Pediatric subspecialist locations were merged with hospital referral regions to generate the percentage of hospital referral regions with a pediatric subspecialist, the mean and SD of the ratio of pediatric subspecialists to 100 000 children across hospital referral regions, the distribution maps of that ratio, the coefficients of variation (CVs) of that ratio, and the comparisons with previous results. In this case, the CV (calculated as the SD divided by the mean of the subspecialist-to-child population ratio multiplied by 100) indicated the relative distribution density of subspecialists across hospital referral regions, which was useful for comparison, as the means varied widely.

Statistical Analysis

We also used subspecialty size and mean driving distance (Table 1) to examine associations. The analysis used correlation coefficients from linear regression analysis to measure the association of subspecialty size with geographic proximity, assuming that a larger subspecialty size may be associated with lower driving distances.

Statistical analysis was performed using SAS software, version 7.1 (SAS Institute Inc), and mapping was performed using Tableau software, version 2019.2 (Tableau Software). Data were analyzed from July 8, 2019, to December 17, 2019.

Results

The number of certified pediatric subspecialists 70 years or younger increased by 76.8%, from 13 789 subspecialists in 2003 to 24 375 subspecialists in 2019 (Table 1). The increase in subspecialists occurred in all fields but varied widely by subspecialty, with the smallest absolute increases in adolescent medicine (396 to 501 subspecialists [26.5%]), pediatric nephrology (530 to 644 subspecialists [21.5%]), and sports medicine (82 to 251 subspecialists [206.1%]). In contrast, the largest absolute increases in subspecialists occurred in pediatric critical care medicine (1013 to 2453 subspecialists [142.2%]) and neonatal-perinatal medicine (3588 to 4959 subspecialists [38.2%]). Six subspecialties (developmental-behavioral pediatrics, pediatric critical care medicine, pediatric emergency medicine, pediatric gastroenterology, pediatric rheumatology, and sports medicine) had more than double the number of certifications in 2019 compared with 2003.

In 2019, the mean driving distance to the closest subspecialist was lowest for the 2 largest subspecialties, with neonatal-perinatal medicine at a mean (SD) distance of 11.8 (19.0) miles and pediatric cardiology at a mean (SD) distance of 17.3 (26.0) miles. Among ABP-administered certifications, 2 of the smallest subspecialties had the greatest mean driving distance, with pediatric rheumatology at a mean (SD) distance of 42.8 (59.9) miles and adolescent medicine at a mean (SD) distance of 35.8 (44.9) miles. Every subspecialty studied had a reduction in mean driving distance compared with 2003. Similar to the reductions in mean distance, decreases were also observed in the 75th and 95th percentiles of driving distance; for instance, pediatric cardiology decreased by 7 miles in the 75th percentile and 19 miles in the 95th percentile, and pediatric rheumatology decreased by 20 miles in the 75th percentile and 68 miles in the 95th percentile.

Table 2 depicts the 2019 driving distance to a pediatric subspecialist, aggregated in discrete ranges. Among the 7 largest subspecialties (neonatal-perinatal medicine, pediatric cardiology, pediatric critical care medicine, pediatric emergency medicine, pediatric endocrinology, pediatric gastroenterology, and pediatric hematology-oncology), the overall proportion of children residing within 10 miles of a subspecialist increased slightly, with the greatest absolute increase (41.7 million to 50.2 million children [12%]) in the subspecialty of neonatal-perinatal medicine. All other subspecialties indicated a slight decrease in the proportion of children residing within 10 miles of a subspecialist, with the greatest absolute decreases in pediatric rheumatology (32.9 million to 23.9 million children [−12%]) and adolescent medicine (35.1 million to 26.8 million children [−11%]). The percentage of children in the 2 longer-distance ranges (41-80 miles and >80 miles) decreased for each subspecialty, with the greatest decreases observed in developmental-behavioral pediatrics (14.6 million to 5.5 million children [−12%]) and sports medicine (21.9 million to 10.8 million children [−15%]) in the distance range of more than 80 miles. The **Figure** maps these distance ranges for 2 subspecialties; a separate dashboard using the same methods explores each subspecialty.[15]

We used the subspecialty numbers and mean distance to examine 2 associations: (1) pediatric subspecialty size with mean distance and (2) change in subspecialty size with change in mean distance (Table 1). First, among the subspecialties analyzed in 2006,[6] the mean driving distance in 2019 was associated with the number of subspecialists, such that every 1-U increase in the number of subspecialists was associated with a decrease of 0.0055 miles (ρ = .80) of driving distance, which represented an increase from 2003 (ρ = .68). Second, a linear regression analysis of the estimate of the ratio of absolute change in mean driving distance per 1-U increase in the number of pediatric subspecialists (ie, the absolute change of subspecialists among the 15 subspecialties we could calculate) indicated a positive association that was not statistically significant (β_1 = −0.0069 miles; ρ = .37).

As a measure of dispersion over time, the presence of a pediatric subspecialist in any one of the 306 hospital referral regions improved for all subspecialties, with the greatest absolute increase from 2003 to 2019 observed in sports medicine (22%), developmental-behavioral pediatrics (16%), and pediatric emergency medicine (14%; **Table 3**). The subspecialty of neonatal-perinatal medicine continued to be the most evenly distributed, covering 294 hospital referral regions (96%). Despite overall increases, 10 of the subspecialties did not cover half (153 of 306) of the hospital referral regions. In addition, the distribution of subspecialists remained uneven. Eleven subspecialties (adolescent medicine, child abuse pediatrics, developmental-behavioral pediatrics, hospice and palliative medicine, medical toxicology, pediatric nephrology, pediatric pulmonology, pediatric rheumatology, sleep medicine, sports medicine, and transplant hepatology), which experienced the smallest increases between 2003 and 2019, had mean ratios of subspecialists per 100 000 children of 1.0 or less. In comparison, subspecialties with the greatest absolute increases had mean ratios of more than 2.0, with the mean (SD) ratio of neonatal-perinatal medicine at 5.57 (4.05), pediatric cardiology at 2.54 (3.02), pediatric critical care medicine at 2.43 (2.67), pediatric emergency medicine at 2.03 (2.80), and pediatric hematology-oncology at 2.17 (2.84). Nonetheless, the

Table 2. Estimated Proportion of US Children by Driving Distance to a Pediatric Subspecialist

Subspecialty	Children, % (No., in millions)									
	2003					2019				
	≤10 miles	11-20 miles	21-40 miles	41-80 miles	>80 miles	≤10 miles	11-20 miles	21-40 miles	41-80 miles	>80 miles
ABP certifications[a]										
Adolescent medicine[b]	48 (35.1)	6 (4.4)	10 (7.3)	17 (12.4)	19 (13.9)	37 (26.8)	18 (13.5)	15 (11.0)	15 (11.2)	14 (10.6)
Child abuse pediatrics	NA	NA	NA	NA	NA	33 (24.2)	22 (16.2)	17 (12.6)	15 (11.0)	13 (9.2)
Developmental-behavioral pediatrics	46 (33.6)	6 (4.4)	12 (8.8)	16 (11.7)	20 (14.6)	43 (31.6)	20 (14.3)	15 (11.1)	15 (10.6)	8 (5.5)
Neonatal-perinatal medicine	57 (41.7)	10 (7.3)	17 (12.4)	12 (8.8)	4 (2.9)	69 (50.2)	13 (9.8)	11 (7.9)	5 (3.9)	2 (1.2)
Pediatric cardiology	52 (38.0)	8 (5.8)	15 (11.0)	17 (12.4)	7 (5.1)	58 (42.5)	16 (11.4)	14 (10.2)	9 (6.8)	3 (2.2)
Pediatric critical care medicine	52 (38.0)	8 (5.8)	16 (11.7)	18 (13.2)	7 (5.1)	57 (41.3)	15 (11.2)	14 (10.0)	11 (7.7)	4 (2.9)
Pediatric emergency medicine[b]	50 (36.6)	6 (4.4)	11 (8.0)	18 (13.2)	16 (11.7)	56 (40.8)	13 (9.4)	12 (9.0)	11 (8.4)	8 (5.5)
Pediatric endocrinology	51 (37.3)	7 (5.1)	13 (9.5)	19 (13.9)	11 (8.0)	53 (39.0)	16 (11.8)	14 (10.6)	11 (8.4)	5 (3.4)
Pediatric gastroenterology	49 (35.8)	7 (5.1)	13 (9.5)	19 (13.9)	12 (8.8)	53 (38.9)	16 (11.5)	14 (10.5)	12 (8.5)	5 (3.7)
Pediatric hematology-oncology	52 (38.0)	8 (5.8)	15 (11.0)	17 (12.4)	8 (5.8)	56 (41.0)	15 (11.0)	15 (10.7)	10 (7.3)	4 (3.2)
Pediatric infectious diseases	50 (36.6)	7 (5.1)	13 (9.5)	18 (13.2)	12 (8.8)	49 (35.8)	17 (12.4)	15 (11.2)	13 (9.2)	6 (4.5)
Pediatric nephrology	48 (35.1)	6 (4.4)	13 (9.5)	16 (11.7)	16 (11.7)	42 (30.8)	19 (14.0)	16 (11.7)	13 (9.6)	10 (7.0)
Pediatric pulmonology	49 (35.8)	7 (5.1)	13 (9.5)	19 (13.9)	13 (9.5)	48 (35.2)	17 (12.8)	15 (10.9)	12 (9.1)	7 (5.2)
Pediatric rheumatology	45 (32.9)	5 (3.7)	10 (7.3)	16 (11.7)	24 (17.5)	33 (23.9)	20 (14.9)	15 (11.3)	14 (10.1)	18 (12.9)
Total ABP certifications, mean	50 (36.5)	7 (5.1)	13 (9.6)	17 (12.5)	13 (9.5)	49 (35.9)	17 (12.4)	15 (10.6)	12 (8.7)	8 (5.5)
Joint board certification										
Allergy and immunology[c]	50 (36.6)	9 (6.6)	14 (10.2)	16 (11.7)	11 (8.0)	50 (36.3)	19 (13.8)	15 (10.9)	11 (8.0)	6 (4.2)
Hospice and palliative medicine[b]	NA	NA	NA	NA	NA	33 (24.4)	20 (14.6)	18 (12.8)	16 (12.0)	13 (9.3)
Medical toxicology[b]	NA	NA	NA	NA	NA	7 (5.1)	12 (8.7)	15 (10.9)	13 (9.5)	53 (38.8)
Sleep medicine[b]	NA	NA	NA	NA	NA	33 (24.0)	19 (14.2)	17 (12.1)	18 (13.1)	13 (9.8)
Sports medicine[b]	42 (30.7)	5 (3.7)	8 (5.8)	17 (12.4)	30 (21.9)	31 (22.7)	21 (15.6)	17 (12.2)	16 (11.8)	15 (10.8)
Transplant hepatology[b]	NA	NA	NA	NA	NA	21 (15.1)	17 (12.2)	16 (11.7)	16 (11.8)	31 (22.3)
Total joint board certifications, mean	46 (33.6)	7 (5.1)	11 (8.0)	17 (12.1)	21 (15.0)	29 (21.3)	18 (13.2)	16 (11.8)	15 (11.0)	22 (15.9)
Total ABP and joint board certifications, mean	50 (36.1)	7 (5.1)	13 (9.4)	17 (12.4)	14 (10.2)	43 (31.5)	17 (12.6)	15 (11.0)	13 (9.4)	12 (8.7)

Abbreviations: ABP, American Board of Pediatrics; NA, not applicable.

[a] As of 2007, neurodevelopmental disabilities certification was no longer offered by the American Board of Medical Specialties and is now solely offered by the American Board of Psychiatry and Neurology.

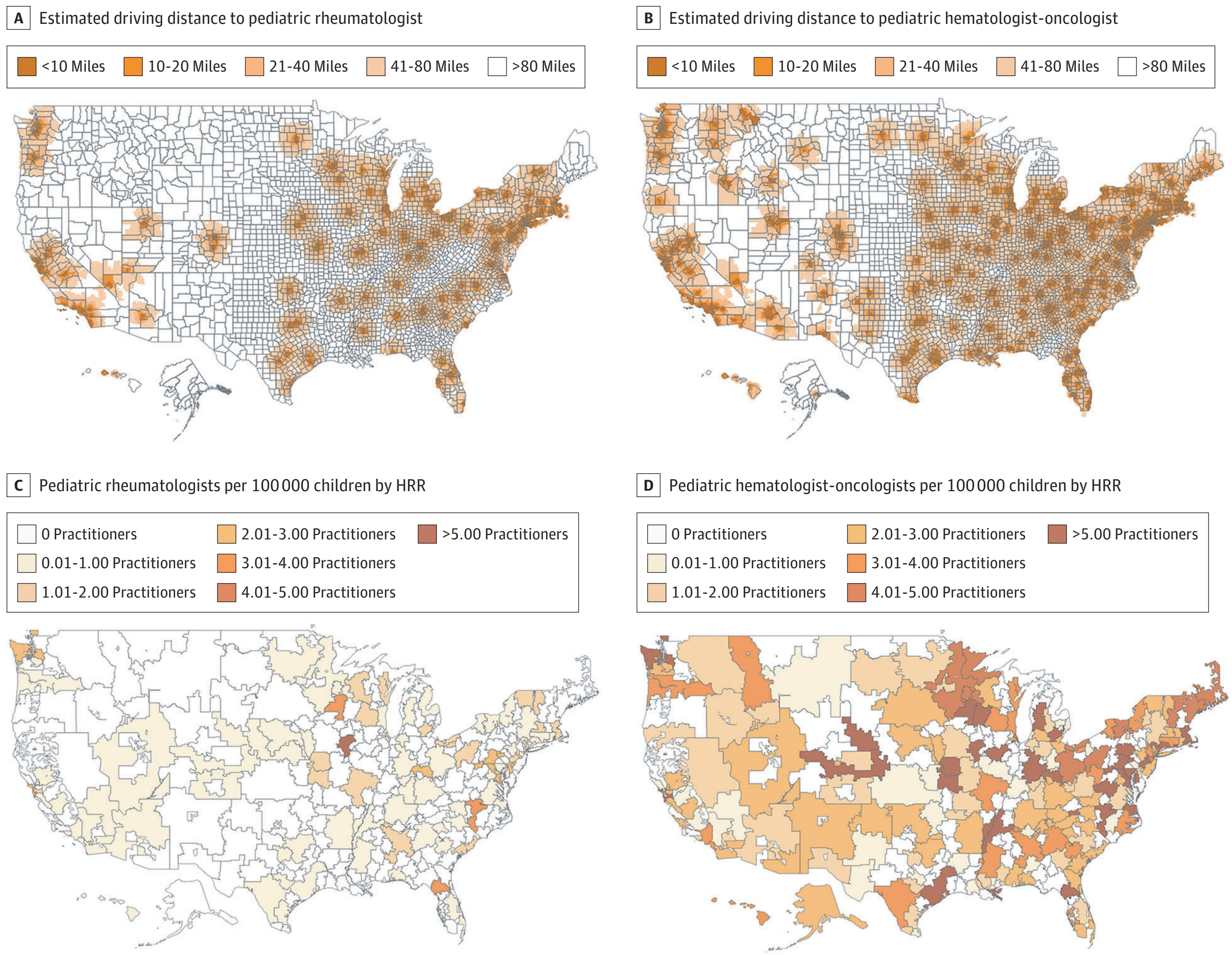
[b] Certification was offered by 1 or more boards within the American Board of Medical Specialties. Analysis included only subspecialists certified by the ABP.

[c] Analysis included only physicians who were currently certified in general pediatrics and allergy/immunology.

mean ratio across the compared subspecialties for all from 2003 to 2019.

Even among subspecialties with lower numbers of pediatric health care practitioners, such as pediatric rheumatology, the improvement in distribution was associated with a reduction of 625 000 children to 287 000 children per subspecialist across hospital referral regions. The CVs improved (ie, decreased) for almost all subspecialties, with the notable exceptions of adolescent medicine and pediatric hematology-oncology, suggesting that their increase in numbers may have occurred in areas with existing subspecialists. The 4 newer joint board–certified subspecialties (ie, offered after 2003) had high CVs (sleep medicine, CV = 165; hospice and palliative medicine, CV = 206; transplant hepatology, CV = 304; and medical toxicology, CV = 394), suggesting wide ratio variations across the hospital referral regions and, furthermore, numerous areas without a subspecialist. The Figure maps subspecialist-to-child population ratios by hospital referral region

Figure. Distance to Pediatric Subspecialists and Subspecialist-to-Child Population Ratios



A, Estimated driving distance to pediatric rheumatologist. B, Estimated driving distance to pediatric hematologist-oncologist. A separate dashboard explores each subspecialty.[15] C, Pediatric rheumatologists per 100 000 children by hospital referral region (HRR). D, Pediatric hematologist-oncologists per 100 000 children by HRR. A separate dashboard explores each subspecialty.[16]

for 2 subspecialties; a separate dashboard using the same methods explores each subspecialty.[16]

Discussion

The results demonstrated a substantial increase in the number of subspecialists between 2003 and 2019, as measured by the absolute number of US pediatric subspecialists, and an increased ratio of pediatric subspecialists to children by hospital referral region. However, the number of subspecialists remained unequal, as 11 subspecialties had 1 or fewer subspecialists per 100 000 children. In contrast, subspecialties with the greatest absolute increases (neonatal-perinatal medicine, pediatric cardiology, pediatric critical care medicine, pediatric emergency medicine, and pediatric hematology-oncology) had subspecialist-to-child population ratios of more than 2.0.

The data also indicated an improvement in patient geographic proximity, as measured by mean driving distance, and a shift in the proportion of children in the shorter-distance categories compared with 2003. In all subspecialties, the percentage of children in the most distant ranges (ie, 41-80 miles and >80 miles) decreased. However, in some instances, the proportion of children living in the closest proximity to a subspecialist (<10 miles) decreased, even with an increased number of subspecialists. This decrease may indicate that physicians' offices or families are moving out of densely populated urban environments, which are often near academic medical centers. Nonetheless, this decrease in proportion in the less-than-10-mile range appears to have been balanced by increases in patient proximity in the ranges of 11 to 20 miles and 21 to 40 miles. Distance changes may have been compounded by the overall increase in the US urban population during the period studied, but additional data sources and study are needed to further delineate the factors involved.[17]

Although the data described a more widespread geographic distribution of subspecialists, individual maps indicated distribution differences across regions and by subspe-

Table 3. Availability of Pediatric Subspecialists Across Hospital Referral Regions and Ratio of Pediatric Subspecialists to Children, 2003 vs 2019

Subspecialty	HRRs with a pediatric subspecialist, %[a]			HRR subspecialist-to-child ratio per 100 000 children				Absolute change from 2003 to 2019		Percent change from 2003 to 2019	
	2003	2019	Absolute change from 2003 to 2019	2003 Mean (SD)	2003 CV	2019 Mean (SD)	2019 CV	Mean (SD)	CV	Mean (SD)	CV
ABP certifications[b]											
Adolescent medicine[c]	40	46	6	0.37 (0.61)	167	0.44 (0.78)	175	0.07 (0.17)	7.7	20.1 (27.2)	4.6
Child abuse pediatrics	NA	43	NA	NA	NA	0.32 (0.53)	163	NA	NA	NA	NA
Developmental-behavioral pediatrics	37	53	16	0.30 (0.55)	186	0.70 (1.06)	150	0.40 (0.51)	−35.8	134.9 (92.4)	−19.3
Neonatal-perinatal medicine	88	96	8	4.10 (3.10)	76	5.57 (4.05)	73	1.47 (0.95)	−3.4	35.8 (30.5)	−4.4
Pediatric cardiology	68	74	6	1.51 (1.78)	118	2.54 (3.02)	119	1.03 (1.24)	0.9	68.4 (69.9)	0.8
Pediatric critical care medicine	56	69	13	0.99 (1.23)	125	2.43 (2.67)	110	1.44 (1.44)	−15.2	145.8 (117.3)	−12.2
Pediatric emergency medicine[c]	48	62	14	0.89 (1.32)	147	2.03 (2.80)	138	1.14 (1.48)	−9.3	128.2 (111.8)	−6.3
Pediatric endocrinology	54	62	8	0.79 (1.10)	138	1.27 (1.52)	120	0.48 (0.42)	−18.2	60.6 (38.2)	−13.2
Pediatric gastroenterology	53	66	13	0.67 (0.90)	135	1.40 (1.66)	119	0.73 (0.76)	−16.1	108.9 (84.9)	−11.9
Pediatric hematology-oncology	64	68	4	1.41 (1.71)	121	2.17 (2.84)	130	0.76 (1.13)	9.5	54.1 (65.8)	7.8
Pediatric infectious diseases	54	61	7	0.77 (1.04)	135	1.08 (1.44)	133	0.31 (0.40)	−1.8	40.4 (38.4)	−1.4
Pediatric nephrology	43	49	6	0.49 (0.76)	156	0.60 (0.93)	157	0.11 (0.17)	0.5	21.9 (23.0)	0.3
Pediatric pulmonology	51	58	7	0.62 (0.96)	154	0.98 (1.31)	133	0.36 (0.35)	−20.8	58.2 (36.1)	−13.5
Pediatric rheumatology	26	36	10	0.16 (0.35)	218	0.35 (0.72)	206	0.19 (0.37)	−11.9	117.2 (104.6)	−5.4
Joint board certifications											
Allergy and immunology[d]	57	65	8	0.64 (0.80)	124	1.10 (1.31)	119	0.46 (0.51)	−5.1	71.8 (63.4)	−4.1
Hospice and palliative medicine[c]	NA	40	NA	NA	NA	0.3 (0.63)	206	NA	NA	NA	NA
Medical toxicology[c]	NA	10	NA	NA	NA	0.02 (0.08)	394	NA	NA	NA	NA
Sleep medicine[c]	NA	39	NA	NA	NA	0.27 (0.44)	165	NA	NA	NA	NA
Sports medicine[c]	19	41	22	0.09 (0.26)	287	0.28 (0.51)	184	0.19 (0.25)	−103.1	210.1 (97.4)	−35.9
Transplant hepatology[c]	NA	17	NA	NA	NA	0.08 (0.24)	304	NA	NA	NA	NA

Abbreviations: ABP, American Board of Pediatrics; CV, coefficient of variation; HRR, hospital referral region; NA, not applicable or not available.

[a] A total of 306 HRRs were analyzed.

[b] As of 2007, neurodevelopmental disabilities certification was no longer offered by the American Board of Medical Specialties and is now solely offered by the American Board of Psychiatry and Neurology.

[c] Certification was offered by 1 or more boards within the American Board of Medical Specialties. Analysis included only subspecialists certified by the ABP.

[d] Analysis included only physicians who were currently certified in general pediatrics and allergy/immunology.

cialty. However, changes in hospital referral region distributions across the subspecialties from 2003 to 2019 suggest that the increase in subspecialty numbers may result in dispersion to underrepresented regions. These findings (sparse distribution in rural areas but wider dispersion over time) are echoed by US county maps[18] and state trend graphs[19] that were developed separately using address data from the ABP.

Care by Other Specialists

The data sources used did not allow inclusion of physicians practicing in a given area who were not certified by the ABP. Separate research has suggested that physicians external to the ABP certification system are practicing in pediatric subspecialties.[10] Notably, the same previous work revealed substantial training gaps among large numbers of these practitioners. Nonetheless, given the 2016 estimate that, across all licensed physicians, approximately 21% are practicing in subspecialties without any active certification,[20] exclusions made in this area likely underrepresented those practicing medicine in a pediatric subspecialty. In a similar manner, adult-trained subspecialists may be providing specialized care to children when access to pediatric-trained practitioners is limited. This care may be helpful in many instances, particularly when a specific disease or disease presentation has similar symptoms and outcomes among children and adults[21]; however, this issue needs to be further studied.

The increasing number of advanced-practice practitioners is relevant to understanding patient access to care. Although data on the number of physician assistants and nurse practitioners were not included in this study, the latest information available reveals that only 1194 physician assistants are currently working among all of the subspecialties analyzed in this study[22]; therefore, minimal consequences for our study's results would be expected, particularly with only one-quarter of those 1194 physician assistants practicing neonatal-perinatal medicine. Current data were unavailable for pediatric nurse practitioners, despite a large increase in the number of nurse practitioners overall.[23] An analysis from 2010 revealed that most pediatric nurse practitioners working in a subspecialty environment were focused on outpatient care,[24] and their current clinical implications are not fully understood.

Access to Care

Within the data sets used, we were unable to account for care provided at outreach clinics (eg, mobile health applications and satellite office locations); therefore, the physician's reach within geographically isolated communities was potentially underestimated. In addition, data on the use of telehealth applications from the patient or practitioner perspective were not available or measured, although telehealth applications have been reported to be associated with improved access to care in many instances.[25]

Local studies of both outreach clinics and telehealth applications have reported decreased travel distances by patients[26,27]; however, further research regarding their national implications and the ways in which their use can be optimized is warranted when considering national supply of and demand for subspecialists, particularly in regions unable to retain a full-time subspecialist owing to a lack of resources for supportive care, extreme distances, sparse populations, or other factors.

Implications

Although our data indicated an increase in the number and distribution of pediatric subspecialists across the US between 2003 and 2019, substantial variation by subspecialty and region exist. Concerns regarding the provision of care for children with specialized health conditions are supported by the fact that millions of children currently reside at great distances from subspecialty care. Although our statistical analysis only accounted for pediatric subspecialists in the continental United States, maps, including those of Alaska, Hawaii, and Puerto Rico, revealed no apparent differences in geographic access to subspecialists.

These findings have educational and policy implications, as several subspecialties were found to have a limited number of pediatricians entering the field, and professionals in those subspecialties have advocated for an increase in the number of pediatricians entering fellowships.[3] Fellowship program locations and position counts, clinical training sites, and the opening of new programs are currently controlled at the regional or national level. Our findings suggest that more attention could be given to correctly sizing the pediatric subspecialty supply and the supply pipeline and that workforce-related policy should include a consideration of the overall distribution and fellowship program locations. Of note, the federal government supports multiple programs intended to improve access to primary care and to select categories of specialists, but the association between access to subspecialists and primary care practitioners' decisions regarding the locations of their practices is not known. A 2007 study reported that primary care pediatricians were satisfied with the quality of subspecialty care but unsatisfied with the availability of and wait times for appointments in some subspecialty fields, both of which were more pronounced in rural areas.[28]

Although increases in the number of subspecialists and improved subspecialist-to-child population ratios are typically associated with improvements in care delivery, from a practitioner and policy perspective, no standard pediatric subspecialist per 100 000 children ratio for each subspecialty exists that could inform regional and national workforce planning. Within the increases described, an oversupply of practitioners is likely occurring in some locations among the subspecialties studied. This oversupply may, somewhat paradoxically, have negative clinical consequences for supply-sensitive care overuse, as has been reported in studies of the expansion of neonatal intensive care units.[29] Given these complexities, understanding the clinical and economic consequences of the varying ratios would be helpful for interpreting supply-to-demand balances. Hospital referral regions are useful, particularly for comparison (as in this study), but defined pediatric-specific market areas would be more effective for understanding how children's hospitals and other child-specific health care resources are associated with overall access to care. The identification of consensus measures for regional pediatric care may help to inform workforce planning.

Limitations

This study has limitations. As in the 2006 analysis by Mayer,[6] our study used the most current subspecialist addresses on file to permit comparisons over time; however, the list of addresses included a mixture of practice locations and personal residences. Previous research using data from the American Medical Association Masterfile described the ways in which a mixture of addresses at scale may simultaneously overestimate suburban-area access and underestimate urban-area access owing to differences in physicians' home vs practice addresses.[30] In addition, we were unable to determine full-time clinical equivalents, which likely resulted in overestimation of the current distribution of subspecialists, as our analysis assumed 1 full-time clinical equivalent per currently certified subspecialist. Retirement status and practitioner age were not considered, aside from using a cutoff point of aged 70 years and including only those currently certified. Future efforts that model the workforce or examine subspecialist dispersion should account for these factors.

Conclusions

The increase in the number of pediatric subspecialties in the past 16 years has likely resulted in improved geographic access to care for millions of children with serious medical conditions in the United States. This increase is associated with improvements in the distribution of subspecialists overall, even if the increased distribution is not balanced across subspecialties. Even so, practitioners in several subspecialties continue to express concern about the total number of subspecialists and the overall outlook for future increases in the number of subspecialists.[31] This study indicates that distribution gaps remain substantial across several subspecialties. From the child and family perspective, millions of children reside 1.5 hours or more from access to needed specialty care. As in the past, future workforce policy should consider ways to improve the subspecialist distribution landscape through individual funding levers or other mechanisms, such as coordinated planning with training programs. Additional mechanisms could include extension of the existing workforce through outreach clinics, telemedicine applications, and team-based care. Further research should model the implications of accurate full-time equivalence indicators, the noncertified workforce, the retirement of subspecialists, and the migration of subspecialists over time.

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Critical revision of the manuscript for important intellectual content: All authors.
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