Association between Mergers and the Provision of Pediatric Services in Rural Hospitals from 2011 to 2021

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Abstract

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Objective: To evaluate the association between hospital mergers and provision of pediatric inpatient services in rural hospitals from 2011-2021.

Methods: Using data from the American Hospital Association Annual Survey and Centers for Medicare & Medicaid Services Provider of Service files, we conducted a retrospective cohort study of U.S. rural hospitals. The primary outcome was provision of pediatric inpatient services. We used logistic regression with robust standard errors to examine the association between hospital mergers and pediatric service provision, adjusting for hospital characteristics and geographic factors.

Results: Among 2,205 rural hospitals, 100 (4.5%) underwent a merger during the study period. Merged hospitals were larger (mean 107.5 vs 58.3 beds) and less likely to be critical access hospitals (14.0% vs 56.9%) than independent hospitals. After adjusting for hospital and geographic characteristics, merged hospitals had 30% lower odds of providing pediatric services compared to independent hospitals (OR=0.70, 95% CI: 0.51-0.97). Each year was associated with 2% lower odds of pediatric service provision (OR=0.98, 95% CI: 0.97-0.99), with similar declines in both merged and independent hospitals. Regional variation was substantial, with hospitals in the South showing particularly lower odds of pediatric service provision (OR=0.40, 95% CI: 0.36-0.43) compared to the Midwest.

Conclusion: Rural hospital mergers are significantly associated with reduced probability of providing pediatric inpatient services. As hospital consolidation continues, policies that balance financial sustainability with preservation of essential pediatric services are needed to prevent exacerbation of rural health disparities for children.

Introduction

More than 12 million children live in rural communities in the US.[1] Rural communities rely on local hospitals to provide acute care services, ranging from emergency department to definitive inpatient care.[2] Yet, despite holding a pivotal role within the community, rural hospitals frequently experience financial strain resulting in closures.[3] Between 2005-2024, 193 rural hospitals closed in the US,[3] leaving many communities without local access to critical healthcare services. Seeking to avoid closures and gain financial stability, many rural hospitals pursue mergers, with mergers and acquisitions increasing dramatically over the past decade. Between 2010-2019, hospital mergers in the US increased by nearly 80%.[4] Over the same period, 22% of rural hospital markets lost a competitor due to closure or merger.[5]

For mergers that do not lead to closures, many may contribute to financial stabilization of the acquired hospital, yet lead to reductions in service-line provision.[6] Studies show that rural hospitals undergoing mergers are more likely to eliminate surgical and maternal/neonatal services, while mental health services often remain stable.[6] This variability on service line provision after a rural hospital merges may be more significant for pediatric services, which are uniquely vulnerable in rural areas. Although there are more than 2 million children in the US who live in rural communities, loss of pediatric units and regionalization of definitive pediatric care has disproportionately impacted rural areas.[7–9] Unlike adult services, pediatric inpatient care often struggles to achieve the patient volumes necessary to sustain financial viability,[10] leading to its reduction or elimination even in financially stable hospitals.

The consequences of losing pediatric services extend beyond healthcare access. Rural families may face increased travel time, delays in care, and greater financial and logistical burdens, [11–14] exacerbating disparities in health outcomes for rural children.[15,16] These changes may also disrupt continuity of care, undermine preventative healthcare efforts, and strain tertiary care centers tasked with managing higher patient volumes from distant areas.[17,18]

Despite the growing prevalence of rural hospital mergers and the recognized decline in pediatric services[7,19,20] no studies have examined how mergers specifically impact the provision of pediatric inpatient care in rural hospitals. Understanding this relationship is essential for ensuring equity in access to acute care for children and for informing policies aimed at sustaining essential services in rural communities.

This study evaluates the association between mergers and the probability of providing pediatric inpatient services in rural hospitals from 2011-2021. By comparing merged and independent hospitals across time, we aimed to identify what role mergers play in the decline of pediatric services.

Methods

We conducted a retrospective cohort study to examine the association between hospital mergers and the probability of providing pediatric services in US rural hospitals from 2011-2021.

Data Sources

We merged two nationally representative data sources for this analysis. The first data source was the American Hospital Association's Annual Survey of Hospitals (AHA).[21] The AHA data are collected annually through a voluntary survey of more than 6200 hospitals.[21] Variables include information on pediatric units, pediatric bed counts, service lines, hospital system affiliations, and physician staffing.

The second data source was the Centers for Medicare and Medicaid (CMS) provider of service file (POS).[22] The POS is publicly available and collected quarterly from all institutions that receive Medicare funding. The Hospital & Non-Hospital Facilities files provide information on hospital certification, termination, accreditation, and types of services provided.[22] As the raw data represents all active providers, there are more than 150,000 entities described quarterly within the POS.

Identification of U.S. Acute Care Hospitals and Defining Pediatric Services

To identify acute care hospitals within the US, we undertook a six-step process to clean and merge the AHA with the POS files. We undertook this process laterally between datasets within a single year then merged the yearly-merged files longitudinally over time. A detailed description of each step for the lateral process is in **Supplement 1**.

In step 1, we limited the POS datafile to the maximum available quarter (e.g., quarter 4), and then limited to short term, general, critical access, and pediatric hospitals. In step 2, we merged the partially cleaned POS data with the raw AHA file. We merged between files based on CMS provider number and address. This resulted in his resulted in three generated files for each year: (1) merged AHA + POS, (2) unmerged, cleaned AHA, and (3) unmerged, cleaned POS. For step 3, we cleaned the merged AHA + POS file, filtering the AHA data by facility type, US states (excluding territories), and excluding hospitals with CLOSED in the name. At this step, we verified legitimacy of the remaining hospitals against the Dartmouth Atlas Good Hospital List, merging on CMS provider number, which was available for 2011-2019. For step 4, we then undertook a manual removal of duplicates between the three generated files. In step 5, we further cleaned the unmerged AHA and POS files by the same criteria as in step 3. Then in the final step 6, we finalized the data set by combining the merged AHA + POS file with the unmerged, cleaned AHA file, and lastly the unmerged, clean POS file. To longitudinally merge across time, we generated a unique Universal ID for each individual hospital that can be used to identify the same hospital across time.

To identify the presence of hospital-based pediatric services, we developed an enhanced method utilizing data from the merged dataset. To do this, we first merged in a pediatric-specific hospital-level dataset, the National Pediatric Readiness Project (NPRP) Survey. The NPRP is a pediatric-specific assessment administered through the Emergency Medical Services for Children Data Center conducted in 2013 and 2021. The assessment was completed by an individual with specific knowledge of pediatric care at each institution, often an emergency department nurse manager. A total of 5150 emergency departments were contacted in 2021, excluding Veteran Affairs and prison hospitals. The survey includes hospital classifications, pediatric services, and information on board certification of physicians.[23] Given the pediatric specific focus of this survey and its extensive use for pediatric health services research,[23–28] we chose to use the NPRP as the benchmark for provision of pediatric services.

Using the data from 2021, we employed logistic regression, two decision tree analyses – random forest analysis (RF)[29] and gradient-boosted trees analysis (XGBoost),[30] and rule-based sequential reasoning to predict hospital services when using a combined AHA+POS dataset, using the NPRP as the pediatric benchmark. Exploratory variables included: all pediatric service-line and pediatric psychiatry variables, hospital bed counts, and facility characteristics as defined in the AHA and POS (**Supplement 2**). We applied a five-fold cross-validation strategy using

80% of the merged dataset between AHA and POS as the training set and the remaining 20% of data were held as a test set for final evaluation. We bound the machine learning models to avoid signs of overfitting, with consistent performance metrics across training and test sets, indicating pattern capture.

Lastly, we created a rule-based sequential reasoning process to predict services. Incorporating patterns from the machine learning algorithms with subject matter expertise, we developed a set of logical conditions. First, we assessed when the AHA and the POS were discordant across each service line, e.g., when the AHA data show a particular hospital has newborn services, but the POS data do not. Using these discordant pairs, we calculated true positives, true negatives, false positives, and false negatives relative to the NPRP for the AHA and POS (**Supplement 3**). This informed calculations of accuracy for the sequential rule-based model with and without missing data for each dataset.

We then established service line specific rules to determine when either the AHA or POS should be used to predict the provision of services (as recorded in the NPRP), in cases of discordance (**Supplement 4**). We intentionally established rules that would emphasize prediction sensitivity over specificity. For example, if a hospital provided neonatal intensive care according either the AHA or POS, we assumed that hospital indeed provided the service. This resulted in four outcomes for each service line: (1) AHA + POS agree there is existence of a service line, (2) AHA + POS agree there is not existence of a service line, (3) AHA + POS are discordant, and (4) no data. In the third scenario, the established rules were applied sequentially. We compared the performance of each model against the NPRP, establishing test statistics for each dataset combination used for prediction (**Supplement 5**).

Lastly, we utilized multiple imputation for scenarios with single-year discrepancies in service line provision. For example, if a hospital denoted that they provided pediatric services in 2015 and either had no data or data that showed no services in 2016 but again provided services in 2017, we imputed data for 2016 identifying provision of services for that year.

Mergers Identification

To identify individual hospital service-line changes related to mergers or acquisitions, we identified all cases of mergers or acquisitions within the dataset, as identified by the AHA's Annual Landscape Changes documentation <citation>. In many cases within the data, when two hospitals merged, they became a single entity with a single Universal ID, even if both institutions continue to physically exist. We identified 7 different types of possibilities for mergers when the acquired hospital does not close (**Table 1**). We then systematically "de-constructed" the merged entities according to a system developed by Cooper et al. when using AHA and POS data. We then imputed pediatric services leveraging the pediatric variables in the pre-merger year, plus post-merge changes from the merged entity. Each type of merger had a different imputation approach (**Supplement 6**). This allowed the merged entities then to continue to be tracked year-to-year by their Universal ID but with individual data for each hospital.

Study Population

We included all US rural hospitals that provided general inpatient pediatric services at any time between 2011 and 2021. We classified hospitals into two groups each year: (1) rural hospitals that experienced a merger that year, and (2) independent rural hospitals. We used the 2010 Rural-Urban Commuting Area (RUCA) codes to determine rurality (**Supplement 7**).[31]

Dependent, Independent, and Predictive Variables

The primary dependent variable was a binary indicator of pediatric services by a hospital in each hospital-year. The independent variable was hospital merger status, classified as merged or independent. Our model included hospital and community level predictor variables. Hospital-level predictors included critical access hospital designation, bed count, and ownership type (for-profit, non-profit, and government). Community-level predictors included level of rurality (isolated, small rural, micropolitan), and state.

Statistical Analysis

The primary analysis examined the association between hospital mergers and the probability of providing pediatric inpatient services using logistic regression with robust standard errors to account for potential heteroscedasticity. The model included an interaction term between merger status and year to assess whether merger effects varied over time. Initial testing revealed minimal state-level variance in the provision of pediatric services, supporting the use of a fixed-effects logistic regression approach rather than a multilevel model.

The primary outcome was a binary indicator of pediatric service provision by hospital-year. The key independent variable was hospital merger status. Control variables included facility characteristics (facility type, bed count), ownership type (for-profit, non-profit, government), rurality level (large rural, small rural, isolated), and geographic region. Year was included as a centered continuous variable to capture temporal trends. Due to perfect prediction in some categories, facility type was retained as a control variable but not interpreted directly. Similarly, state-level effects were consolidated into regional indicators to address separation issues while maintaining geographic controls. Lastly, we conducted a sensitivity analysis without the data imputation to check for stability in the findings.

Analyses were conducted using R. Hospital bed counts were standardized prior to analysis. Robust standard errors were calculated to account for potential violations of model assumptions. Model results are presented as odds ratios with 95% confidence intervals. Predictive margins were calculated to illustrate the relationship between merger status and pediatric service provision over time.

Results

Between 2011-2021, there were 2205 rural hospitals within the US, 100 (4.5%) underwent a hospital merger. Hospitals that underwent a merger were larger (mean bed count, 107.5 [standard deviation (SD) 151.0]) than independent hospitals (mean bed count 58.3 [SD 62.8]) and a lower percentage were critical access hospitals (14%, N=14) compared to independent hospitals (56.9%, N=1198) (**Table 2**). Merged hospitals also had a larger percentage in large rural communities (53%, N=53) and a higher concentration in the northeast (17%, N=17) and the south (54%, N=54) than independent hospitals. They had similar overall distribution of pediatric services with 75% of merged hospitals (N=75) and 70.1% of independent hospitals (N=1476) having inpatient pediatric services with a median licensed pediatric bed count for both of 0.0 (Merged Interquartile Range [IQR] 0, 1; Independent IQR 0,0). Thirteen percent of rural hospitals that underwent a merge subsequently closed (N=13), compared to 6.7% (N=142) for independent hospitals over the time period.

Hospitals that underwent mergers had 30% lower odds of providing pediatric services compared to independent hospitals (OR=0.70, 95% Confidence Interval [CI]: 0.51-0.97), adjusting for hospital characteristics and geographic factors. There was a significant overall declining trend in pediatric service provision, with each year associated with 2.5% lower odds of services (OR=0.98, 95% CI: 0.97-0.99) (**Figure 1**). The interaction between merger status and time was not statistically significant (OR=0.97, 95% CI: 0.87-1.08). When testing for autocorrelation of provision of services through time, presence or absence of pediatric service is strongly correlated initially with the provision of services in the next year (**Supplement 8**). After 3 years, however, this relationship diminishes.

Geographic analysis revealed substantial regional variation in pediatric service provision. Compared to the Midwest reference group, hospitals in the South had 60.8% lower odds of providing pediatric services (OR=0.39, 95% CI: 0.36-0.43), while differences in the Northeast (OR=0.89, 95% CI: 0.80-0.99) and West (OR=0.93, 95% CI: 0.86-1.02) were less pronounced. This regional disparity was particularly evident among merged hospitals, where those in the South represented 54.9% of all rural hospital mergers but maintained lower odds of pediatric service provision even after adjusting for hospital characteristics and rurality level.

Hospital size was strongly associated with pediatric service provision, with each standard deviation increase in bed count associated with 4.61 times higher odds of providing services (95% CI: 4.09-5.21). Compared to isolated rural hospitals, facilities in large rural (OR=2.14, 95% CI: 1.94-2.36) and small rural areas (OR=1.89, 95% CI: 1.75-2.03) had significantly higher odds of maintaining pediatric services. Government (OR=0.73, 95% CI: 0.68-0.78) and non-profit hospitals (OR=0.78, 95% CI: 0.70-0.87) had lower odds of providing pediatric services compared to for-profit facilities.

A sensitivity analysis using non-imputed pediatric service data yielded consistent but stronger associations compared to the primary analysis. When examining only directly observed service provision, hospitals that underwent mergers had 44.2% lower odds of providing pediatric services (OR=0.56, 95% CI: 0.41-0.76) compared to the 30.2% reduction observed in the primary analysis. The temporal decline in pediatric services remained nearly identical (OR=0.98, 95% CI: 0.97-0.99), as did the non-significant interaction between merger status and time (OR=0.98, 95% CI: 0.89-1.09).

Discussion

Our study revealed that 4.5% of rural hospitals underwent a merger between 2011 to 2021. Hospitals that merged were larger, less rural, had significantly lower odds of providing pediatric services, and had a higher percentage of closures when compared to rural independent hospitals. Pediatric services in rural hospitals steadily declined over the study period for both the merged and independent facilities. These trends raise concerns regarding the accessibility of pediatric care in rural communities.

Over the past decade, two in five children needing acute care in rural communities sought care at a hospital with minimal to no pediatric capacity – twice as often as children in urban areas.[32] This inability for children to receive general inpatient care locally contributes disparities in quality and access to care for children in rural areas.[33] Families living as far as 600 miles from the nearest pediatric referral center[34] face significant social and financial burdens due to interfacility transfer and hospitalizations.[11] Furthermore, local hospitals in rural areas serve as vital employers, and service-line reductions or closures after a merger can have rippling financial impact within these communities.[35]

Given these challenges, health policies must prioritize equitable access to pediatric services in rural communities. e The financial profitability of pediatric services is low, even in high-volume, high-acuity children's hospitals.[10] Pediatric services have lower profit margins compared to adult care[10] and a substantial portion of pediatric care is covered by Medicaid,[36] which often has lower reimbursement than private insurance.[37,38] In addition, pediatric patient volume often is fluctuant with seasonality,[39] making the logistics of managing costs and staffing challenging.[40] So while a hospital merger may help to sustain the operations of a hospital by bolstering financial viability, in our data that does not translate to the continuation of provision of pediatric services.

Current policies that support viability of rural hospitals focus primarily on financial stabilization, with limited if any consideration for service line preservation or community access needs. For example, the Critical Access Hospital designation improves financial viability of rural hospitals through cost-based reimbursement, yet has no specific provisions to support pediatric care.[41] Policymakers could address this gap by incorporating targeted service line specific subsidies or enhanced Medicaid reimbursement rates for pediatric services.

Additionally, mechanisms such as Certificates of Public Advantage (COPAs) are regulatory instruments that could be broadened to better safeguard access to essential services post-merger.[42] Currently COPAs are used primarily for price regulation, but could be expanded to include service-line retention agreements, such as requiring hospitals to maintain pediatric services for a defined period after a merger. Tennessee's COPA framework, which incorporates quality and access measures in addition to price regulation,[43] could serve as a model. Our temporal analysis revealed that the initial presence of pediatric services predicted continued pediatric services for up to three years, after which this relationship weakened. This pattern may indicate a critical window during which intervention could help preserve services post-merger.

The geographic concentration of rural hospital mergers in the South may further complicate these disparities. With over half of rural hospital mergers occurring in a region with 60% lower odds of pediatric service provision, the combined effects of regional and merger-related trends could compound barriers to pediatric care access. This suggests that policy interventions may need to be geographically targeted, with particular attention to areas where multiple risk factors for service loss exist simultaneously.

Beyond financial incentives, supporting and building partnerships between rural hospitals and larger pediatric centers may offer sustainable solutions. Shared staffing models and telehealth programs could help sustain pediatric expertise locally while reducing operational costs.[44–46] As pediatric services consolidate into regional centers, collaboration may prove mutually beneficial. More research is needed to explore the role of these partnerships in supporting equitable access for rural communities.

This study has several limitations. First, there is no universally accepted benchmark to define hospitals that provide pediatric services. While we attempted to define services in a rigorous way, we prioritized sensitivity over specificity in our service-line model. This means that we may overestimate the number of hospitals that provide pediatric services. Next, we defined rurality by commuting codes, which may not fully reflect the hospital service area. This is particularly true in highly rural areas where a single present hospital may cast a very wide service area extending beyond the commuting zone. RUCA codes also are static based on decennial census data and are not yet available for the 2020 census. As such, the use of the 2010 RUCA codes may not fully reflect shifts or changes in rural populations over the last decade. In addition, while trends in consolidation of pediatric services are happening in rural and urban areas, our findings may not be generalizable to urban settings where the impact of a merger and acquisition is likely mitigated by additional factors that impact hospital-level decisions on maintaining services. Lastly, while our data can estimate hospitals that provide pediatric services, we cannot draw any conclusions about the volume of pediatric patients serviced nor the quality of care they received.

Conclusion

Rural hospital mergers are significantly associated with loss of inpatient general pediatric services. Healthcare policies that balance financial sustainability with the preservation of pediatric services in rural communities are needed to ensure that rural mergers do not exacerbate health disparities for children.

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Table 1: Possible Case Scenarios for Provision of Pediatric Services after Hospital Merger[1]

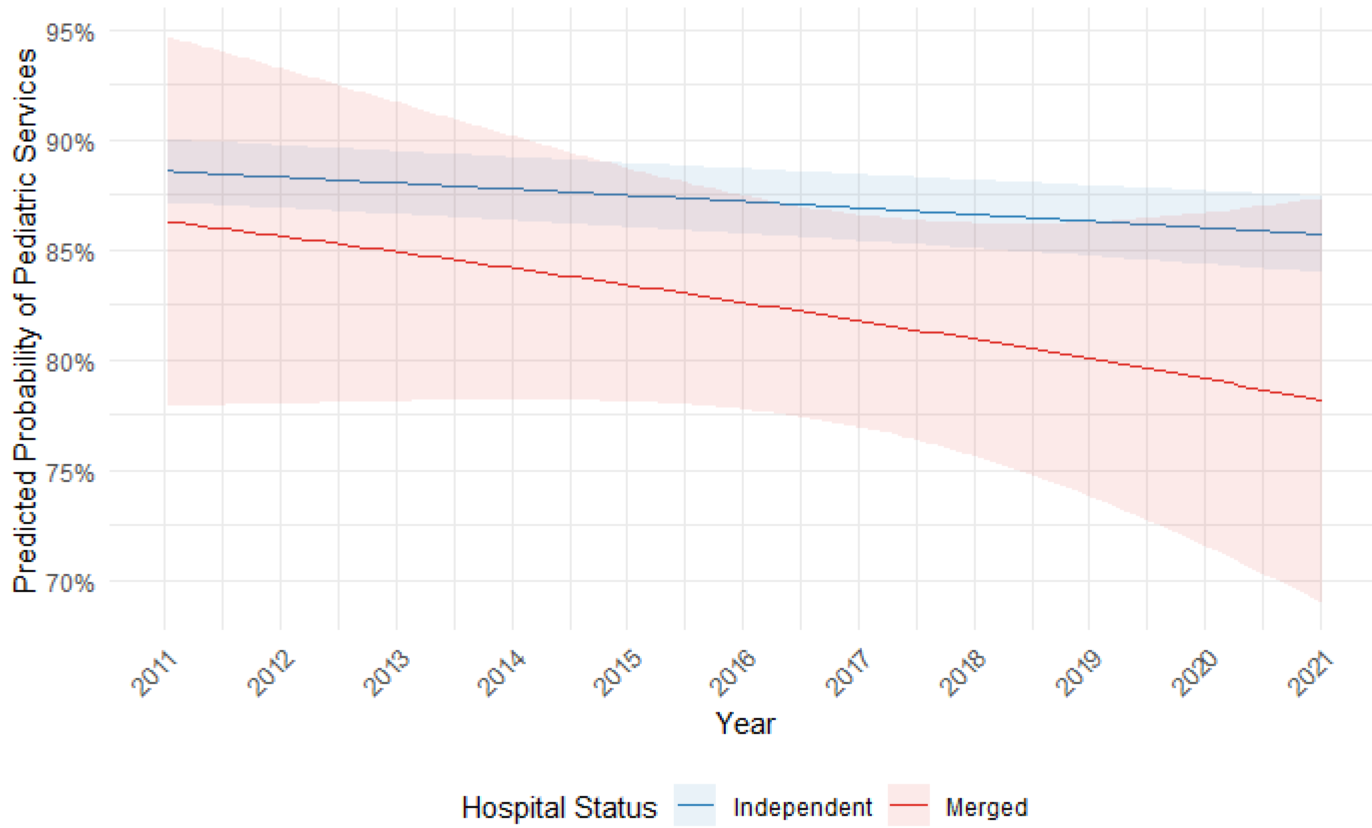
Case	Hospital 1	Hospital 2	Merged Entity Services	Demerged Imputation Hospital 1	Demerged Imputation Hospital 2
A	Has service	Has service	Has service	Has service	Has service
B	Does not have service	Does not have service	Does not have service	Does not have service	Does not have service
C	Has service	Does not have service	Has service	Has service	Does not have service
D	Has service	Does not have service	Does not have service	Does not have service	Does not have service
E	Has service	Has service	Does not have service	Does not have service	Does not have service
F	Does not have service	Does not have service	Services Gained	Has service	Has service

[1] Excluding hospital mergers resulting in closure of one of the hospitals.

Table 2: Characteristics of Merged and Independent Rural Hospitals

Characteristic	Independent Hospitals N=2105	Merged Hospitals N=100
Hospital-level characteristics		
Critical Access Hospitals (%)	1198 (56.9)	14 (14.0)
Bed count		
Mean (SD)	58.3 (62.8)	107.5 (151.0)
Median (IQR)	25.0 (25.0-72.0)	60.5 (26.5- 139.2)
Ownership Type (%)		
For-Profit	1155 (54.9)	57 (57.0)
Government	686 (32.6)	22 (22.0)
Non-Profit	264 (12.5)	21 (21.0)
Pediatric care		
Presence of inpatient services	1476 (70.1)	75 (75.0)
Dedicated pediatric beds		
Mean (SD)	1.0 (3.2)	2.1 (5.0)
Median (IQR)	0 (0-0)	0 (0-1)
Hospital Closures	142 (6.7)	13 (13.0)
Community-level characteristics		
Rurality (%)		
Large Rural	733 (34.8)	53 (53.0)
Small Rural	878 (41.7)	33 (33.0)
Isolated	494 (23.5)	14 (14.0)
State/region		
Northeast	150 (7.1)	17 (17.0)
South	754 (35.8)	54 (54.0)
Midwest	816 (38.8)	14 (14.0)
West	385 (18.3)	15 (15.0)

Figure 1 Probability of Pediatric Services in Merged and Independent Rural Hospitals from 2011-2021



Supplement 1 Data Processing Steps for Merging of the AHA and POS to identify Acute Care Hospitals in 2021

<table>
<tr><td>Merging Process 2021</td><td>Starting N (hospitals)</td><td>Finished N (Hospitals)</td></tr>
<tr><td colspan="3">AHA + POS Merge</td></tr>
<tr><td>Clean POS data preliminarily
POS limited to max quarter 4
Limit to hospitals: filter(PRVDR_CTGRY_SBTYP_CD == 1)
Limited to short term, CAH, Peds: filter(GNRL_FAC_TYPE_CD %in% c("1", "4", "6", "11"))</td><td>155,262</td><td>After PRVDRCTGRY = 13,137

After PRVDR and then SHORT TERM = 10,623</td></tr>
<tr><td>Merge partially cleaned POS data with raw AHA file
Merge conducted by:
1. MCR_NUM & Zip matched
2. MCR_NUM & "city name" matched
3. MCR_NUM alone matched
4. Zip alone matched
Duplicates filtered out by MCR_NUM and Zip codes
5. standardized hospital names by "upper case" and matched on name
6. standardized by matching street addresses standardized by "upper case"
For hospitals that matched ONLY on MCR_NUM or ZIP, manually checked for verification</td><td>AHA File: 6,201

POS File: 10,623</td><td>5,507</td></tr>
<tr><td>Cleaning of the merged AHA + POS file
AHA Hospital Service Code: 10, 22, 50-59, 91
Hospital in approved states: filter(!(STATE_CD %in% c("AS", "CN", "FM", "GU", "MH", "MP", "PR", "VI")))
Bed count > 1, as facilities with =<1 bed are stand alone ERs or OP surgery
Removal of hospitals with CLOSED in the name
Provider Number service codes limited to PRVDR_NUM 1-879, 1300-1399, 3300-3399, 4000-4499
Match against GHL by CMS CCN
Manual removal of duplicates → comparing cleaned AHA unmerged and cleaned POS unmerged with cleaned POS+AHA merged, checking for the below with manual google verification, with preference for keeping duplicates in the clean merged POS + AHA (fuzzy matching)
Duplicate CCNs
Standardizing by name & address within the same state</td><td>5,507</td><td>5,032</td></tr>
<tr><td>Cleaning of unmerged AHA and POS files
Unmerged AHA file:</td><td>AHAUNMERGED:460</td><td>AHAUNMERGED:0</td></tr>
</table>

▪ Hospital Service Code: 10, 22, 50-59, 91 ▪ Hospital in approved states: filter(!(STATE_CD %in% c("AS", "CN", "FM", "GU", "MH", "MP", "PR", "VI"))) ▪ Bed count > 1, as facilities with =<1 bed are stand alone ERs or OP surgery ▪ Closed not in the name ▪ Provider Number service codes limited to PRVDR_NUM 1-879, 1300-1399, 3300-3399, 4000-4499 ▪ Match against GHL by CMS CCN o Unmerged POS file: ▪ Hospital in approved states: filter(!(STATE_CD %in% c("AS", "CN", "FM", "GU", "MH", "MP", "PR", "VI"))) ▪ Bed count > 1, as facilities with =<1 bed are stand alone ERs or OP surgery ▪ Closed not in the name ▪ Provider Number service codes limited to PRVDR_NUM 1-879, 1300-1399, 3300-3399, 4000-4499 ▪ Match against GHL by CMS CCN	POSUNMERGED: 5,116	POSUNMERGED: 2,075
• **Finalization of combined dataset of acute care hospitals** o (Merged AHA + POS file) + (Unmerged, clean AHA) + (Unmerged, clean POS)	7,107	7,107

Supplement 2 Variables included in machine-learning models:

data[['InptPedCap_Nursery_YN','InptPedCap_NICU_YN','InptPedCap_PICU_YN','ChildAdmitAdultICU','InptPedCap_PedWard_YN','ChildAdmitAdultWard','OB_SRVC_CD', 'NEONTL_NRSRY_SRVC_CD', 'NEONTL_ICU_SRVC_CD', 'PED_SRVC_CD', 'PED_ICU_SRVC_CD', 'CHLD_ADLSCNT_PSYCH_SRVC_CD', 'obbd', 'obhos', 'nintbd', 'ninthos', 'nicbd', 'nichos', 'pedbd', 'pedhos', 'pedicbd', 'pedichos', 'psycahos', 'PRVDR_CTGRY_SBTYP_CD', 'CMPLNC_STUS_CD', 'SKLTN_REC_SW', 'SSA_STATE_CD', 'GNRL_CNTL_TYPE_CD', 'GNRL_FAC_TYPE_CD', 'CRTFD_BED_CNT','CL_SRVC_CD', 'PHYSN_CNT','genhos','radmchi','pemerhos','psyphchos','alcpdhos']].

Supplement 3 Discordant statistics in the AHA and POS using NPRP as the Gold Standard to inform the Sequential Rule-Based Model

Service Line	**AHA** indicates a hospital has indicated service line	**POS** indicates a hospital has indicated service line	**AHA** when AHA is missing (assumes missing = no)	**POS** when AHA is missing (assumes missing = no)	**Sequential Rule-Based Model** with missing data	**Sequential Rule-Based Model** excluding missing data
Newborn	• Accuracy: 85.11% • Misclassification Rate: 14.89% • Confusion Matrix: ○ TP: 40 ○ TN: 0 ○ FP: 7 ○ FN: 0	• Accuracy: 89.19% • Misclassification Rate: 10.81% • Confusion Matrix: ○ TP: 16 ○ TN: 0 ○ FP: 132 ○ FN: 0	• Accuracy: 51.51% • Confusion Matrix: ○ TP: 0 ○ TN: 410 ○ FP: 0 ○ FN: 386	• Accuracy: 85.43% • Confusion Matrix: ○ TP: 357 ○ TN: 323 ○ FP: 87 ○ FN: 29	• Accuracy: 84.36% • Confusion Matrix: ○ TP: 1460 ○ TN: 1167 ○ FP: 75 ○ FN: 412	• Accuracy: 93.53% • Confusion Matrix: ○ TP: 1817 ○ TN: 1072 ○ FP: 162 ○ FN: 38
Neonatal*	• Accuracy: 75.38% • Misclassification Rate: 24.62% • Confusion Matrix: ○ TP: 49 ○ TN: 0 ○ FP: 16 ○ FN: 0	• Accuracy: 63.23% • Misclassification Rate: 36.77% • Confusion Matrix: ○ TP: 57 ○ TN: 0 ○ FP: 98 ○ FN: 0	• Accuracy: 51.51% • Confusion Matrix: ○ TP: 0 ○ TN: 410 ○ FP: 0 ○ FN: 386	• Accuracy: 75.25% • Confusion Matrix: ○ TP: 105 ○ TN: 395 ○ FP: 15 ○ FN: 281	• Accuracy: 79.09% • Confusion Matrix: ○ TP: 1427 ○ TN: 2283 ○ FP: 206 ○ FN: 445	• Accuracy: 79.32% • Confusion Matrix: ○ TP: 1168 ○ TN: 670 ○ FP: 161 ○ FN: 318
General Pediatrics	• Accuracy: 67.89% • Misclassification Rate: 32.11% • Confusion Matrix: ○ TP: 74 ○ TN: 0 ○ FP: 35 ○ FN: 0	• Accuracy: 41.06% • Misclassification Rate: 58.94% • Confusion Matrix: ○ TP: 432 ○ TN: 0 ○ FP: 301 ○ FN: 0	• Accuracy: 33.54% • Confusion Matrix: ○ TP: 0 ○ TN: 267 ○ FP: 0 ○ FN: 529	• Accuracy: 64.95% • Confusion Matrix: ○ TP: 378 ○ TN: 139 ○ FP: 128 ○ FN: 151	• Accuracy: 69.65% • Confusion Matrix: ○ TP: 1718 ○ TN: 451 ○ FP: 573 ○ FN: 372	• Accuracy: 71.95% • Confusion Matrix: ○ TP: 1407 ○ TN: 312 ○ FP: 450 ○ FN: 220
Pediatric Intensive Care	• Accuracy: 88.30% • Misclassification Rate: 11.70% • Confusion Matrix: ○ TP: 151 ○ FN: 0 ○ FP: 20 ○ FN: 0	• Accuracy: 19.15% • Misclassification Rate: 80.85% • Confusion Matrix: ○ TP: 76 ○ TN: 0 ○ FP: 18 ○ FN: 0	• Accuracy: 78.14% • Confusion Matrix: ○ TP: 0 ○ TN: 622 ○ FP: 0 ○ FN: 174	• Accuracy: 62.81% • Confusion Matrix: ○ TP: 49 ○ TN: 599 ○ FP: 23 ○ FN: 125	• Accuracy: 80.10% • Confusion Matrix: ○ TP: 233 ○ TN: 2283 ○ FP: 26 ○ FN: 572	• Accuracy: 81.94% • Confusion Matrix: ○ TP: 282 ○ TN: 2249 ○ FP: 49 ○ FN: 509

Supplement 4 Sequential rule-based model

Service-line	(+) Service definition	(-) Service definition
Newborn care	AHA = 1, OR AHA = missing & POS = 1	AHA = 0, OR AHA = missing & POS = 0
Neonatal intensive care	AHA =1, OR POS =1	AHA and POS = 0 AHA = missing & POS =0 POS = missing & AHA = 0
General pediatric care	AHA =1, OR POS =1	AHA and POS = 0 AHA = missing & POS =0 POS = missing & AHA = 0
Pediatric intensive care	AHA = 1, OR AHA = missing & POS = 1	AHA = 0, OR AHA = missing & POS = 0

Unknown: AHA & POS = Missing

Supplement 5 Exploratory Model Test Characteristics a Combined Dataset using the NPRP as the Gold Standard for Provision of Pediatric Services

	Sensitivity (95% CI)	Specificity (95% CI)	PPV (95% CI)	NPV (95% CI)	LR + (95% CI)	LR- (95% CI)
Newborn care, N=1,855						
Rule-based	0.98 (0.97, 0.99)	0.87 (0.85, 0.89)	0.92 (0.91, 0.93)	0.97 (0.95, 0.98)	7.65 (6.61, 8.87)	0.02 (0.02, 0.03)
DTA - RF	0.97 (0.95, 0.99)	0.78 (0.73, 0.84)	0.89 (0.87, 0.92)	0.93 (0.89, 0.97)	4.44 (3.44, 5.74)	0.04 (0.02, 0.07)
DTA - XGboost	0.96 (0.94, 0.98)	0.85 (0.80, 0.90)	0.92 (0.90, 0.95)	0.92 (0.88, 0.96)	6.33 (4.60, 8.72)	0.05 (0.03, 0.08)
Logistic regression	0.87 (0.84, 0.90)	0.82 (0.76, 0.87)	0.90 (0.87, 0.93)	0.76 (0.71, 0.82)	4.70 (3.53, 6.26)	0.16 (0.12, 0.21)
Neonatal intensive care, N=874						
Rule-based	0.98 (0.97, 0.99)	0.51 (0.49, 0.53)	0.48 (0.46, 0.51)	0.98 (0.97, 0.99)	2.00 (1.91, 2.10)	0.03 (0.02, 0.06)
DTA- RF	0.82 (0.77, 0.86)	0.94 (0.91, 0.96)	0.91 (0.88, 0.95)	0.87 (0.83, 0.90)	13.33 (8.77, 20.25)	0.20 (0.15, 0.25)
DTA - XGboost	0.87 (0.83, 0.91)	0.95 (0.93, 0.97)	0.94 (0.91, 0.97)	0.90 (0.87, 0.93)	18.24 (11.44, 29.07)	0.14 (0.10, 0.19)
Logistic regression	0.71 (0.66, 0.77)	0.96 (0.93, 0.98)	0.93 (0.89, 0.96)	0.81 (0.77, 0.85)	16.31 (9.89, 26.91)	0.30 (0.25, 0.36)
General pediatric inpatient care, N=2,071						
Rule-based	0.83 (0.82, 0.85)	0.43 (0.40, 0.46)	0.75 (0.73, 0.77)	0.55 (0.52, 0.59)	1.46 (1.38, 1.55)	0.39 (0.35, 0.44)
DTA- RF	0.88 (0.85, 0.91)	0.43 (0.35, 0.51)	0.84 (0.80, 0.87)	0.53 (0.44, 0.62)	1.55 (1.34, 1.79)	0.28 (0.20, 0.38)
DTA - XGboost	0.92 (0.90, 0.95)	0.42 (0.34, 0.50)	0.84 (0.81, 0.87)	0.62 (0.52, 0.72)	1.58 (1.37, 1.82)	0.19 (0.13, 0.27)
Logistic regression	0.88 (0.85, 0.91)	0.40 (0.32, 0.48)	0.83 (0.80, 0.86)	0.51 (0.42, 0.60)	1.48 (1.28, 1.69)	0.30 (0.22, 0.40)
Pediatric intensive care, N=791						
Rule-based	0.36 (0.32, 0.39)	0.98 (0.97, 0.98)	0.85 (0.81, 0.89)	0.81 (0.80, 0.83)	16.46 (12.29, 22.05)	0.66 (0.62, 0.69)
DTA- RF	0.62 (0.56, 0.68)	0.98 (0.96, 0.99)	0.95 (0.92, 0.99)	0.77 (0.73, 0.81)	26.87 (13.46, 53.64)	0.39 (0.33, 0.45)
DTA - XGboost	0.61 (0.55, 0.67)	0.97 (0.95, 0.99)	0.94 (0.91, 0.98)	0.76 (0.72, 0.80)	21.23 (11.44, 39.40)	0.40 (0.34, 0.46)
Logistic regression	0.53 (0.47, 0.59)	0.96 (0.94, 0.98)	0.91 (0.86, 0.95)	0.72 (0.68, 0.76)	13.04 (7.71, 22.06)	0.49 (0.43, 0.56)

Abbreviations: AHA, American Health Association Annual Survey; DTA-RF, Decision Tree Analysis – Random Forest; DTA-XGBoost, Decision Tree Analysis – XGBoost; LR, Likelihood Ratio; NPV, Negative Predictive Value; POS, Center for Medicare and Medicaid Services Provider of Service File; PPV, Positive Predictive Value

Supplement 6: Rules for imputation in hospital mergers

- **Case A**: A pediatric serving hospital merged with another pediatric serving hospital; the merged entity also indicated pediatric services. Solution: Impute both new hospitals as having the pediatric services.
- **Case B**: A non-pediatric serving hospital merged with another non-pediatric serving hospital; the merged entity had no pediatric services. Solution: Impute both continued without pediatric services.
- **Case C**: A pediatric serving hospital merged with a non-pediatric serving hospital; the merged entity had pediatric services. Solution: We assumed that the original pediatric serving hospital continued to provide pediatric services and the original non-pediatric serving hospital continued to not provide those services.
- **Case D**: A pediatric serving hospital merged with a non-pediatric serving hospital; the merged entity did not have pediatric services. Solution: The original pediatric serving hospital closed their pediatric services, and the original non-pediatric serving hospital made no change.
- **Case E**: A pediatric serving hospital merged with another pediatric serving hospital; the merged entity did not indicate obstetric services. Solution: Neither hospital continues to have pediatric serving services.
- **Case F**: A non-pediatric serving hospital merged with a non-pediatric serving hospital; the merged entity had pediatric serving services. Solution: Both hospitals started providing the service.
- **Case G**: Multiple Hospitals Merger with Service Status Variation:
    - **General Rule:**
        - If at least one original hospital had the service AND the merged entity has the service: Status quo is maintained all hospitals in the merger are considered to have the service
        - If none of the original hospitals had the service BUT the merged entity has the service (or vice-versa): All hospitals are imputed to now have the service
    - Example scenario:
        - 3 independent hospitals undergo a merger
            - Hospital 1: Has service
            - Hospital 2: Does not have service
            - Hospital 3: Does not have service
        - Merged Entity Status: Has services
            - Demerged Imputation Hospital 1: Has service
            - Demerged Imputation Hospital 2: Does not have service
            - Demerged Imputation Hospital 3: Does not have service

Supplement 7 2010 Rural-Urban Commuting Area Codes and Classifications

Geographic-classification		
Urban focused: 1.0, 1.1, 2.0, 2.1, 3.0, 4.1, 5.1, 7.1, 8.1, and 10.1.		
Micropolitan focused: 4.0, 4.2, 5.0, 5.2, 6.0, and 6.1		
Small Rural Town focused: 7.0, 7.2, 7.3, 7.4, 8.0, 8.2, 8.3, 8.4, 9.0, 9.1, 9.2		
Isolated Small Rural Town focused: 10.0, 10.2, 10.3, 10.4, 10.5, and 10.6		
Code	**RUCA Designation**	**Description**
1	Metropolitan area core	Primary flow within an urbanized area (UA)
2	Metropolitan area high commuting	Primary flow 30% or more to a UA
3	Metropolitan area low commuting	Primary flow 10% to 30% to a UA
4	Micropolitan area core	Primary flow within an Urban Cluster of 10,000 to 49,999 (large UC)
5	Micropolitan high commuting	Primary flow 30% or more to a large UC
6	Micropolitan low commuting	Primary flow 10% to 30% to a large UC
7	Small town core	Primary flow within an Urban Cluster of 2,500 to 9,999 (small UC)
8	Small town high commuting	Primary flow 30% or more to a small UC
9	Small town low commuting	Primary flow 10% to 30% to a small UC
10	Rural areas	Primary flow to a tract outside a UA or UC

Supplement 8 Autocorrelation of Pediatric Services Over Time