ORIGINAL ARTICLE

MRI Utilization and the Associated Use of Sedation and Anesthesia in a Pediatric ACO

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Abstract

Background and Objectives: MRI is commonly used in the pediatric population and often requires sedation or general anesthesia to complete. This study used data from a pediatric accountable care organization (ACO) to investigate trends in MRI utilization and in the requirement for anesthesia to complete MRI examinations.

Methods: The Partners for Kids (PFK) ACO claims database was queried for MRI examination encounters involving patients 0 to 18 years old from 2009 to 2014, with utilization expressed as encounters per 10,000 PFK members-months. Data were limited to 2011 to 2014 to ensure consistent billing of anesthesia services. Encounters were classified according to the presence of procedure codes for anesthesia or sedation.

Results: MRI utilization was approximately constant over the study period at 11 to 12 encounters per 10,000 member-months. The need for anesthesia increased from 21% to 28% of encounters over 2011 to 2014. The latter increase was shared across 1- to 6-year-old, 7- to 12-year-old, and 12- to 18-year-old subgroups. In multivariable regression analysis of monthly utilization, increasing need for anesthesia could not be attributed to secular trends in patient demographics or types of examinations ordered. Paid cost data were available for outpatient MRIs, and MRIs with sedation accounted for an increasing share of these costs (from 22% in 2011 to 33% in 2014).

Conclusion: There was an increasing need for anesthesia services to complete MRI examinations in this pediatric population, resulting in increasing cost of MRI examinations and presenting a challenge to ACO cost containment.

Key Words: Accountable care organization (ACO), MRI, anesthesia, sedation, utilization

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INTRODUCTION

Diagnostic imaging is both a common and essential component in guiding the management of clinical care for patients across all age groups and accounts for $100 billion in annual health care expenditure in the United States [1]. Although an initial surge in utilization of advanced diagnostic imaging was reported in the adult population beginning in the late 1990s, it had reached a plateau by the mid to late 2000s, as demonstrated by studies reporting trends among Medicare enrollees and respondents to the Medical Expenditure Panel Survey [2-7]. Yet, the use of advanced diagnostic imaging, particularly MRI, continues to increase in the pediatric population [8,9]. For the pediatric patient, confined claustrophobic spaces, noise, the need for intravenous placement for contrast administration, and the required immobility to prevent motion artifact during MRI are causes of anxiety and barriers to study completion during diagnostic imaging. Currently, sedation or general anesthesia is the mainstay approach to pediatric patients who require assistance beyond distraction techniques, such as video goggles, to successfully complete diagnostic imaging studies. Although reported rates of adverse events associated with sedation and

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anesthesia for diagnostic imaging are low [10-13], unanticipated cardiopulmonary complications may still occur [14-16].

To date, available evidence on trends in the use of sedation and general anesthesia for MRI has been largely limited to single-center studies and analyses of self-reported surveys after ambulatory care. By contrast, we analyze data on MRI utilization from Partners for Kids (PFK), an accountable care organization (ACO) that accepts full financial and clinical risk for 330,000 low-income children in central and southeastern Ohio [17,18]. The primary objective of the current study was to determine the overall utilization of MRI in the PFK population, as well as the utilization of MRI with anesthesia or sedation in this population. Secondary objectives were to describe the population costs associated with MRI, MRI study characteristics, and patient demographics for patients requiring sedation or anesthesia to complete their MRI examination.

METHODS

After obtaining Institutional Review Board approval from Nationwide Children's Hospital (NCH; Columbus, Ohio), the database for PFK claims was queried for claims data from encounters involving patients age 0 to 18 years undergoing one or more MRI examinations from 2009 to 2014. PFK is an ACO that accepts full financial and clinical risk for 330,000 low-income children in central and southeastern Ohio. Through subcontracted arrangements with five of Ohio's Medicaid managed care plans, PFK is paid an age- and gender-adjusted capitation fee per child per month that covers medical, dental, vision, pharmacy services and administrative expenses. PFK is fully responsible for managing and reimbursing providers for care. The managed care organizations retain a percentage of the administrative capitation rate to provide claims processing, member relations, and standard insurance management functions. PFK is considered an intermediary organization by the Ohio Department of Insurance and is responsible for maintaining reserves for future claims and re-insurance.

The use of anesthesia or sedation was determined according to whether there were professional or facility claims for anesthesia associated with a particular encounter. The specific Current Procedural Terminology (CPT) codes queried were 01922, 99141 to 99145, and 99148 to 99150, and the specific facility revenue codes queried were 370 and 371. Encounters meeting this criterion were described as "MRI with anesthesia," absent further data differentiating depth of sedation or general anesthesia. After reviewing billing practices at NCH, the largest provider of MRI examinations for PFK patients, claims from 2009 and 2010 were excluded due to an unknown number of MRI encounters in these years involving sedation without separately billing for this service. Encounters with a null amount paid were also excluded from analysis.

Patient demographics and scan types ordered were compared between encounters with anesthesia and encounters without anesthesia. Monthly MRI utilization was calculated as the number of MRI encounters per 10,000 members. Annual utilization was expressed as the number of encounters per 10,000 member-months. The percent of MRI encounters with anesthesia was calculated over each month as the monthly number of MRI encounters with anesthesia divided by the monthly total number of encounters.

MRI utilization and the percent of MRI encounters with anesthesia were plotted over each month from January 2011 to December 2014. Least squares regression was used to estimate the linear trend in each of these variables. The fit of this linear trend was assessed using the coefficient of determination (R^2) and comparison to smoothing by locally weighted regression. To test the primary hypothesis, we evaluated whether there was a statistically significant trend in the percent of monthly MRI examinations requiring anesthesia.

Finally, to quantify the cost implications of the trend in MRI with anesthesia, we analyzed the subset of outpatient encounters, because costs for inpatient MRI encounters could not be disaggregated from other costs associated with an inpatient admission. We compared the growth in costs of outpatient MRI with anesthesia, as a percent of all outpatient MRI costs, to growth in utilization of outpatient MRI with anesthesia, as a percent of all outpatient MRI encounters. All analyses were performed in Stata/IC 13.1 (StataCorp, LP, College Station, Texas, USA), and $P < .05$ was considered statistically significant.

RESULTS

Data for 48 months (January 2011 to December 2014) were analyzed, representing 17,221 MRI encounters and 18,543 separate examinations. Encounters at NCH, as compared with other hospitals or freestanding facilities, accounted for 84% of MRI encounters with anesthesia and 50% of MRI encounters without anesthesia. Annual MRI utilization increased from 11.4 encounters per

10,000 member-months in 2011 to 12.1 encounters per 10,000 member-months in 2014. In the overall sample, the most common examinations involved the head (51%) or lower extremities (24%). For examinations of the head, the most common diagnoses reported were headaches, convulsions, and hydrocephalus. The most common diagnoses for examinations of the lower extremities were joint pain and effusion. Overall, 23% of MRI encounters included anesthesia, and this proportion increased from 21% in 2011 to 28% in 2014. The annual median age of all patients undergoing MRI increased from 12.5 years in 2011 to 13.2 years in 2014, and gender composition changed from 48% to 49% female gender over this period. Characteristics of MRI encounters with anesthesia are compared to those without anesthesia in Table 1. Encounters with anesthesia involved patients who were younger, more likely to be male gender, more likely to be undergoing MRI of the head or spine, and more likely to be undergoing MRI in an inpatient setting.

Bivariate least squares regression analysis identified no statistically significant trend of increasing MRI utilization in the overall study sample (Fig. 1) but found an increasing use of anesthesia, as a percent of monthly MRI encounters (Fig. 2). Each month since January 2011, the number of MRI encounters per 10,000 members increased by 0.01 (95% confidence interval [CI]: −0.02 to 0.04; $P = .343$). However, each subsequent month was associated with a 0.21% (95% CI: 0.09% to 0.34%; $P = .001$) increase in the percent of MRI examinations with anesthesia. This

Table 1. Characteristics of MRI encounters in 2011 to 2014, by requirement of anesthesia (N = 17,221 encounters)

Variable	Without Anesthesia (n = 13,240)	With Anesthesia (n = 3,981)	P*
Patient demographics			
Age (y), median (IQR)	14.5 (10.4-16.7)	3.5 (1.1-7.5)	<.001
Female, n (%)	6,663 (50%)	1,790 (45%)	<.001
Inpatient examination, n (%)	992 (7%)	1,247 (31%)	<.001
Scan type, n (%)†			
Head	5,944 (45%)	2,855 (72%)	<.001
Lower extremity	3,972 (30%)	195 (5%)	<.001
Spine	1,499 (11%)	744 (19%)	<.001
Other	2,319 (18%)	757 (19%)	.030

IQR = interquartile range.
*P value by rank-sum test for continuous data and χ^2 test for categorical data.
†Categories are not mutually exclusive.

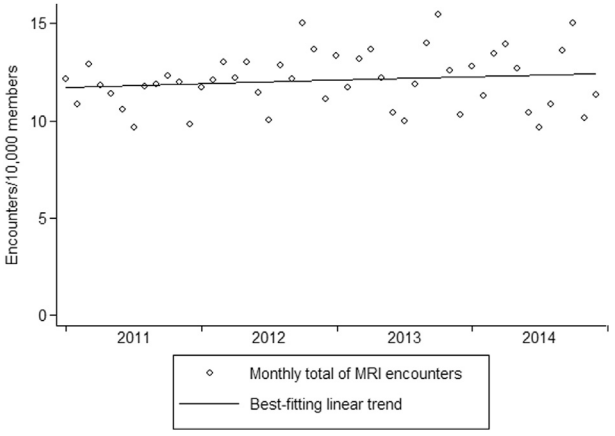

Fig 1. Monthly trend in the number of MRI encounters per 10,000 members.

trend accounted for one-fifth ($R^2 = 0.20$) of the month-to-month variability in the percent of MRI examinations requiring anesthesia, with some deviation from the trend due to a dip in anesthesia requirement in late 2011 to early 2012, confirmed via locally weighted regression smoothing. The number of MRI encounters with anesthesia in a given month fluctuated from 31 to 124, and this variability may have explained sharp differences in utilization of MRI with anesthesia between sequential months (Fig. 2).

Figure 3 disaggregates the trends in monthly requirement of anesthesia to complete MRI examinations by age group. The upward trend in anesthesia requirement was most pronounced in MRIs performed in the 1- to 6-year-old group, with the linear fit indicating a monthly increase of 0.64% (95% CI: 0.30% to 0.97%; $P < .001$) in the proportion of MRI examinations involving anesthesia. The monthly increase

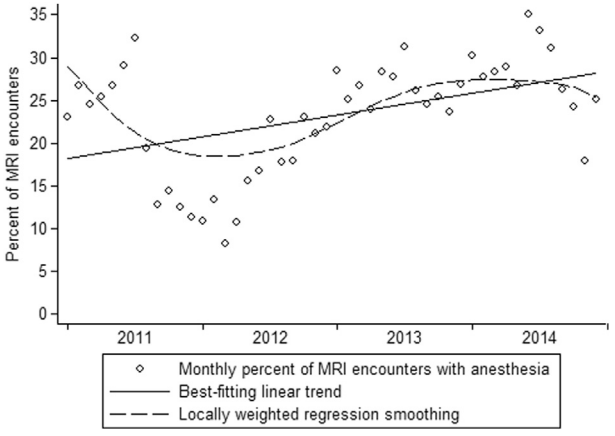

Fig 2. Monthly trend in the proportion of MRI encounters with anesthesia.

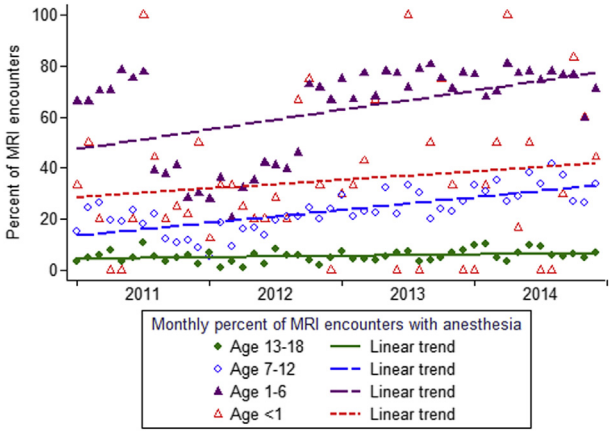

Fig 3. Monthly trend in the number of MRI encounters with anesthesia, by patient age.

in the proportion of MRI examinations with anesthesia was more modest in the 7- to 12-year-old group (monthly increase of 0.42%; 95% CI: 0.30% to 0.54%; $P < .001$). There were no statistically significant linear trends in the proportion of MRI examinations with anesthesia among patients age < 1 year ($P = .343$) or among patients age 13 to 18 years ($P = .051$).

To test for potential explanations of the increase in the percent of MRI encounters with anesthesia (Fig. 2), this variable was regressed on month-level covariates as shown in Table 2. None of the variables considered (median patient age, patient gender composition, body parts scanned, and inpatient versus outpatient setting) attained a statistically significant association with the monthly percent of MRI examinations with anesthesia.

Table 2. Multivariable least squares regression model of month-level predictors of anesthesia use for MRI (percent of monthly encounters with anesthesia) (N = 48 months)

Variable	Unstandardized Coefficient	95% CI	*P*
Patient demographic composition			
Median age	−1.25	−4.48-1.98	.439
Percent female	−0.06	−0.61-0.49	.823
Percent encounters in inpatient setting	0.24	−0.68-1.16	.605
Percent encounters involving scans of			
Head	−0.22	−1.22-0.78	.656
Lower extremity	−0.51	−1.57-0.56	.340
Spine	0.57	−1.00-2.13	.470
Constant	55.41	−56.44-167.26	.323

CI = confidence interval.

This model explained 15% of the month-to-month variability in this outcome ($R^2 = 0.15$). Therefore, the trend toward greater use of MRI with anesthesia could not be explained by changes in the population of patients undergoing MRI, changes in the type of scans ordered, or changes in the use of inpatient as compared with outpatient MRI.

For the purposes of cost analysis, we limited the data to outpatient costs because of the inability to accurately segment inpatient costs directly attributable to MRI. This portion of the analysis included 14,982 outpatient MRI encounters, accounting for 16,026 examinations and $11 million in paid costs. The average cost of outpatient MRI in 2011 was $665 without anesthesia and $902 with anesthesia. In 2014, these average costs were $653 and $1,116, respectively. In the outpatient setting, annual utilization of MRI with anesthesia as a percent of all outpatient MRI examinations increased from 17% in 2011 to 23% in 2014. Annual costs of outpatient MRI per 10,000 member-months increased from $6,878 in 2011 to $8,000 in 2014. Outpacing the trend in utilization, annual costs of outpatient MRI encounters with anesthesia increased from 22% of all outpatient MRI costs in 2011 ($1,515 per 10,000 member-months) to 33% of all outpatient MRI costs in 2014 ($2,659 per 10,000 member-months).

DISCUSSION

Despite previous reports that showed an increase in MRI utilization in the pediatric population [8], our study does not find a statistically significant trend in this direction in the PFK population from 2011 to 2014. However, our study demonstrates a substantial increase in demand for anesthesia services, as a percentage of all MRI encounters, from 21% in 2011 to 28% in 2014. The increased demand for anesthesia services comes at the expense of MRIs being completed without anesthesia in the 1- to 6-year-old and 7- to 12-year-old cohorts. This finding of greater need for anesthesia to complete MRI examinations is novel and significant, especially in the setting of an ACO model dedicated to providing quality care with cost containment.

The most important finding of this study was the increase in the percentage of MRIs with anesthesia, rising from 21% in 2011 to 28% in 2014. This finding is in contrast to a previous analysis by Wachtel et al [8], which found that the proportion of CT or MRI cases requiring anesthesia remained at <10% of cases over the years 1996 to 2008 at a single institution. However, this group noted that by the end of the study period, an

additional 14% of patients who underwent imaging utilized a sedation nurse. It is unclear then if our utilization rate of MRI with anesthesia increasing to 28% of MRI encounters by 2014 was indeed higher than the real utilization Wachtel et al [8] saw or if the difference between the two studies reflects the definitions used.

In the present study, we documented the use of anesthesia when there were paid anesthesia CPT codes in association with an MRI, regardless of the provider type or specialty, or surrogate CPT codes indicating recovery from minimal or moderate sedation. Although it is possible our data underestimated the percent of children undergoing an MRI with minimal or moderate sedation (often seen with nurse-driven sedation services), we expect this bias to be minor, because the largest medical center serving children in PFK plans (NCH) did not have a nurse-only or radiologist-supervised sedation service during the study period, and all sedation for non-intubated patients was provided by a pediatric intensivist or anesthesia care team, with subsequent CPT charges. Similarly, we chose to analyze sedation and general anesthesia as one category (anesthesia) because the use of minimal and moderate sedation is not common in our area and because the difference between deep sedation and general anesthesia was uncertain in the claims data, due to both being billed using the same CPT codes.

The need for anesthesia to complete an MRI is thought to decrease after 5 years of age [8], when children have greater situational awareness and the ability to remain still for longer periods of time. In our study, the largest overall increase in percent of MRI with anesthesia occurred in the age range 1 to 6 years, whereas there was a smaller increase in children age 7 to 12 years. The disaggregation of anesthesia requirement by age reveals two interesting findings. First, the rationale for the increasing need for anesthesia in the older (7 to 12 years old) pediatric population is unclear. In multivariable regression, neither the monthly demographic composition of patients undergoing MRI nor the monthly composition of scans ordered explained the observed increase in the percent of MRI examinations requiring anesthesia. Changes in the age composition of patients requiring anesthesia to complete MRI examinations may be partly the result of patient-centered care and an increasing belief that anesthesia is needed for the comfort of many older children. Second, we saw an increased use of anesthesia services despite the increased promotion and use of simulation and other distraction techniques such as child life and video goggles. Because the data set relied on ICD codes as the indication for MRI, we were unable to elucidate any specific reasons why anesthesia was needed for any given patient to complete their examination. Two possibilities for this trend may be a greater use of higher-resolution (3 Tesla) magnets, which are more susceptible to motion artifacts, or diminishing tolerance of images that are less than pristine. Further clarification of the reasons behind these trends is an opportunity for future investigation. Specifically, a systematic survey of indications for sedation and referring clinician comments may reveal predominant reasons for sedation in patients $>$ 6 years old and whether these reasons may be potentially modifiable.

Examinations of the head accounted for half of the MRI encounters in our data with headache, seizures, and hydrocephalus being the three most common indications for the examination. The incidence of headaches in the pediatric population has increased over the last 30 years [19]. Use of MRI as part of the diagnostic evaluation of headaches continues to be common in children despite consensus to the contrary [20,21]. Conversely, both the American Academy of Neurology and the International League Against Epilepsy recommend MRI for first-time seizures [22-24]. Historically, CT was the modality of choice for diagnosis and surveillance of many intracranial processes including tumors and ventricular shunts. In recent years, there has been a push to reduce the use of CT in exchange for MRI in part to reduce radiation exposure [25]. The increased incidence of headaches in children, recommendations for use of MRI in new seizure diagnosis, and trends away from modalities reliant on radiation likely contributed to the increased utilization of MRI of the head seen in our study. The second largest category of examinations in our study was MRI of the lower extremities, with joint pain and effusion being the leading indications. Increasing utilization of lower extremity MRI may be due to increased reliance on MRI as a diagnostic and risk stratification tool for septic arthritis [26].

Some aspects of the study population and available data limit the conclusions that can be made. First, patients in the study were all enrolled in Medicaid and may have a higher disease burden [27] and different rate of utilization of diagnostic testing compared with the general pediatric population. Second, cost data for MRI exams could not be disaggregated from the costs of each encounter, specifically for inpatient visits, so we limited our analysis of MRI costs to outpatient encounters where the MRI examination plausibly accounted for most or all of costs paid. Third, our cost

analysis was limited to total costs paid, and further detail about the underlying services provided was unavailable. For example, we were unable to answer whether scan times increased over the study period, resulting in a longer anesthetic exposure and subsequent time-based charges. More detailed data on encounter costs are needed to accurately characterize the cost increase attributable to growing use of MRI with anesthesia in both inpatient and outpatient settings. Fourth, 42% of encounters in this study were completed at institutions other than NCH, which may have had different sedation practices. Our use of procedure codes to identify MRI encounters with anesthesia means that if other facilities provided sedation services without billing the primary or secondary codes in the anesthesia set, we would have underestimated the proportion of MRI examinations requiring anesthesia, and the true increase in this proportion may have been even greater than reported here. Finally, we excluded the earliest 2 years of data due to potential confounding by the change in practice at the largest provider of care in the earlier period. The remaining 4 years resulted in analysis of a shorter period than intended; yet, we were still able to extract data on more than 17,000 patient encounters over this period.

Despite these limitations, our study takes advantage of unique data on MRI encounters in a defined pediatric population to estimate trends in MRI and MRI with anesthesia utilization. Our approach overcomes some of the limitations of previous studies, including analysis of single-institution data, self-reporting of MRI utilization, and analysis aggregating MRI and CT examinations. In contrast to previous studies, we have shown an increased utilization of anesthesia services to complete MRI examinations in the pediatric population. This novel finding clarifies current trends in the need for sedation and anesthesia services and will assist with forecasting changing claims on the time and effort of pediatric anesthesia providers.

TAKE-HOME POINTS

- In a pediatric ACO, overall MRI utilization has remained stable.
- Use of sedation or general anesthesia to complete MRI studies in children increased.
- The increasing need for anesthesia services to complete MRI examinations resulted in increased cost of MRI examinations and a challenge to ACO cost containment.

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