Operative Reduction for Developmental Dysplasia of the Hip: Epidemiology Over 16 Years

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Background: The burden of surgical treatment for infantile developmental dysplasia of the hip (DDH) is unknown. We aimed to investigate the epidemiology of operative DDH reductions in the United States and identify potential at-risk populations.

Methods: The Healthcare Utilization Project Kids' Inpatient Database (1997 to 2012) were analyzed. International Classification of Diseases (ICD-9) codes identified inpatient hospitalizations for DDH reductions excluding neuromuscular cases. Hospital variables and patient demographics were captured. Weighted population-level counts were calculated to allow for national estimates.

Results: An estimated 5525 (95% confidence interval, 4907.8-6142.2) operative reductions were performed. In total, 73.3% were open with a mean age at the reduction of 2.3 years (95% confidence interval, 2.1-2.5). In total, 70.0% were female and 42.3% were white. Regional distribution varied: 36.4% of reductions occurred in the West, 22.8% in the South, 21.9% in the Midwest, and 18.9% in the Northeast. Operative reductions decreased over time; open reductions decreased by 5.6% and closed by 53.4%. Mean age at treatment increased from 1.6 to 3.7 years ($P<0.001$). On multivariate analysis, age ($P<0.001$) and geographic location ($P<0.05$) were associated with open reduction. Patients in the West had increased odds of being Hispanic or Asian/Pacific Islander [odds ratio (OR), 4.9, $P<0.001$ and OR, 2.8; $P=0.008$]. In the South and Midwest, the highest income quartile was protective (OR, 0.4; $P=0.001$ and OR, 0.5; $P=0.018$).

Conclusions: The frequency of closed reductions decreased more over time compared with open reductions. However, the mean age of children undergoing reductions increased suggesting a possible delay in diagnosis. The data suggests that there is room for improvement in screening. Targeted research in identified populations may reduce the burden of surgical disease in infantile DDH.

Level of Evidence: Level III.

Key Words: developmental dysplasia of the hip, open reduction, closed reduction

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Developmental dysplasia of the hip (DDH) is the most common congenital anomaly of the lower extremity in children, encompassing a spectrum of anatomic abnormalities ranging from acetabular dysplasia to frank hip dislocation. The reported incidence of DDH ranges between 1 and 28.5 cases per 1000 live births,[1–4] with variation in estimates likely due to different diagnostic definitions, screening protocols, and population heterogeneity.

Recent DDH literature on screening found no consensus on any one approach.[5] The goal of clinical practice guidelines in the United States is to detect dislocated or dislocatable hips early in life, allowing for timely institution of nonoperative treatment. Nonoperative treatment is largely successful in young infants,[6] and delay in diagnosis can lead to more invasive treatment and poorer outcomes later in life.[7] Guidelines published by the American Academy of Pediatrics (AAP),[8,9] and supported in the orthopaedic literature,[10] advocate screening all infants with a physical examination by an experienced clinician followed by targeted ultrasound based on examination and risk factors.

Although some patients may fail nonoperative treatment, requiring operative intervention despite the early diagnosis, other patients may present late. One measure of a successful screening protocol is the number of cases requiring surgical treatment and change in frequency over time. In addition, identifying differences in surgical burden based on geographic region, patient factors, and hospital profile may guide further investigation and allow more targeted educational and surveillance efforts for populations that are particularly at risk. To our knowledge, little epidemiological data exists with regard to the recent trends for surgical treatment of infantile DDH in the United States.

We aimed to study the epidemiology of operative reductions for DDH in the United States using the Healthcare Cost Utilization Project (HCUP) Kids' Inpatient Database (KID). We asked: (1) What is the prevalence of closed and open reductions for DDH across the United States, and has this changed in the past 16 years? (2) How does the distribution of surgical reductions and patient demographics vary across geographic regions? and (3) Are there certain patient, hospital, or regional characteristics that can be identified in patients requiring reduction that can focus future research on diagnosis and treatment of DDH?

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METHODS

Database

The KID is a survey of pediatric hospital discharges compiled by the US HCUP and released at 3-year intervals. Each KID installment constitutes a 1-year sample of US hospital discharges for patients 20 years and below of age at HCUP-participating hospitals. In 2012, 4179 hospitals in 44 states were represented. Using a multilevel sampling algorithm, 80% of nonbirth pediatric discharges, 80% of complicated births, and 10% of uncomplicated births are included. The database includes patient variables such as age, sex, International Classification of Diseases (ICD-9) diagnosis and procedure codes, length of stay, and hospital information such as size, teaching status, and geographic region. Observation sampling weights (discharge weights) based upon hospital characteristics are included, allowing for weighted analyses to produce national or regional estimates. All available KID releases (1997 to 2012) were used in this study, which was exempt from Institutional Review Board oversight. The analysis was subsequently restricted to nonbirth hospitalizations.

Defining Variables

Diagnoses were identified using ICD-9 codes (Table 1). Patients with a diagnosis of hip dysplasia were cross-referenced with the additional major diagnosis codes for spina bifida, Down syndrome, and cerebral palsy to eliminate these categories of disease confounders. Observations of closed or open hip reductions were noted according to ICD-9 procedure codes (797.5 and 798.5, respectively). Other hospital variables of interest included geographic region, children's hospital versus general hospital, location (urban vs. rural), teaching status, and size. Baseline patient-level variables of interest included sex, age, race, income quartile (by ZIP code), and insurance status.

Statistical Analyses

Statistical analyses were performed using Stata 14.2 (StataCorp, College Station, TX) and a commercially available spreadsheet program. KID discharge weights were applied to produce weighted population-level counts describing raw disease and procedure prevalence. SEs were calculated for these values using first-order Taylor series linear approximations. Population-level proportions were also estimated using discharge weights. Confidence intervals (CIs) around these estimates were calculated using logistic transformations. SEs around weighted mean estimates were calculated using first-order Taylor series linear approximations. First, weighted counts were calculated to describe the yearly estimate of open and closed hip reductions among patients with DDH. These values were broken down by geographic region, patient income quartile, race, and insurance status. The proportion of cases attributed to patients by sex and race was calculated. The mean age for open reductions, closed reductions, and all reductions were also defined. All calculations were performed for each KID installment as well as for the combined data set.

Descriptive estimates were compared using Wald and Pearson χ^2 statistics. Multivariate and multinomial regression modeling respecting the database's survey design was conducted to assess the effects of various factors on the odds of undergoing operative reduction and regional variability. The threshold for statistical significance was set at a type I error rate of 0.05.

TABLE 1. ICD-9 Diagnostic Codes Used for Population Identification

Diagnosis	ICD-9 Codes
Spina bifida	741.00-741.03, 741.90-741.93
Down syndrome	758.00
Cerebral palsy	333.71, 343.80, 343.90
Hip dysplasia	754.30-754.35, 755.63

ICD indicates International Classification of Diseases.

RESULTS

From the 6 combined KID database releases (1997 to 2012), an estimated 5525 (95% CI, 4907.8-6142.2) operative reductions were performed nationally for DDH. Patient and hospital demographics are summarized in Tables 2 and 3, respectively. Of the total operative procedures in the sample 73.3% were open (4048.3 open vs. 1476.7 closed). Mean age at the time of surgical reduction was 2.3 years (95% CI, 2.1-2.5).

Closed Versus Open Reduction

Mean age between the type of reduction differed significantly ($P < 0.001$); mean age for closed reductions was 0.8 years (95% CI, 0.6-1.0) and 2.8 years (95% CI, 2.6-3.0) for open reductions. With bivariate testing, no significant

TABLE 2. Total Population Patient Demographic Estimates

	n (%)	95% CI
Estimated population (N)	5525	907.8-6142.2
Age (mean) (y)	2.3	2.1-2.5
Female	3867.5 (70)	3842-4227.7
Race		
White	2338.0 (42.3)	2000.8-2675.1
Black	280.4 (5.1)	217.3-343.5
Hispanic	1385.9 (25.1)	1075.5-1696.2
Asian/Pacific Islander	122.0 (2.2)	85.9-158.2
Native American	26.4 (0.48)	9.4-43.5
Other	317.1 (5.7)	236-398.1
Unknown	1055.3 (19.1)	798.5-1312.0
Insurance type		
Medicare	16.3 (0.3)	0-32.7
Medicaid	2110.5 (38.2)	1823.3-2397.7
Private	2896.3 (52.4)	2499.1-3293.5
Self-pay	92.1 (1.7)	59.7-124.5
No-charge	54.1 (0.98)	5.7-102.5
Other	340.8 (6.2)	240.6-441.0
Unknown	14.9 (0.27)	2.4-27.4
Income (quartile)		
1	735.9 (13.3)	615.6-856.2
2	834.3 (15.1)	712-956.6
3	863.5 (15.6)	733.3-993.7
4	786.8 (14.2)	651.6-922.0

CI indicates confidence interval.

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TABLE 3. Total Population Hospital Demographic Estimates

	n (%)	95% CI
Estimated population (N)	5525	907.8-6142.2
Hospital type		
Rural	133.8 (2.4)	51.6-216.1
Urban/nonteaching	795.2 (14.4)	593.7-996.6
Urban/teaching	4485.4 (81.2)	3902.1-5068.7
Children	869.1 (15.7)	729.6-1005.3
Hospital size		
Small	1191.1 (21.6)	842.0-1540.1
Medium	1642.9 (29.7)	1225.8-2060.0
Large	2580.5 (46.7)	2222.6-2938.3
Region		
Mexican border*	1269.9	50.6-1689.2
Northeast	1043.8 (18.9)	766.2-1321.5
Midwest	1208.8 (21.9)	900.6-1517.0
South	1260.4 (22.8)	1016.3-1504.5
West	2012.0 (36.4)	1540.7-2483.2

*Excluded from total proportion due to missing years.
CI indicates confidence interval.

associations were found between the type of reduction and the size of the hospital ($P=0.1$) or race ($P=0.15$). There were significant differences between groups with regard to sex ($P<0.001$), primary payer type ($P=0.016$), location and teaching status ($P<0.001$), and hospital region ($P=0.004$). On multivariate regression analysis, only age and the geographic region remained significantly associated with undergoing open reduction for DDH.

Trends Over Time

The national estimates for DDH procedural reductions showed a decrease of 22% from 1081.53 cases in 1997 to 843.54 in 2012. There was a significant difference in the number of closed versus open reductions in the sample across years ($P=0.0087$); while the number of open reductions decreased by an estimated 5.6% overall (710.5 cases in 1997 to 670.6 cases in 2012), the number of closed reductions decreased by an estimated 53.4% (371.0 cases in 1997 to 173.0 cases in 2012) (Fig. 1). The relative odds of a patient in our sample being treated with open reduction versus closed reduction increased 2 times over the sample period ($P=0.001$). Age increased over the

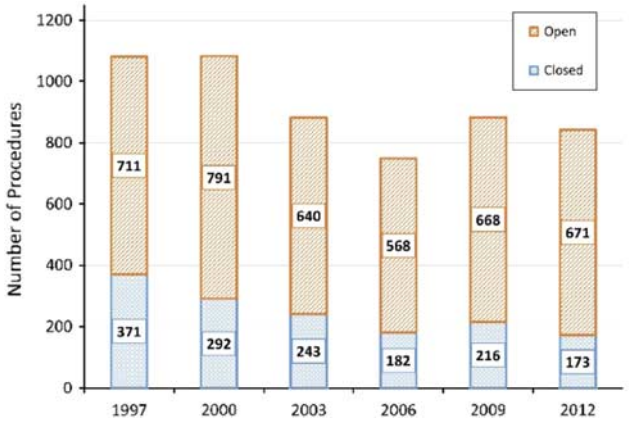

FIGURE 1. Estimated operative reductions by year.

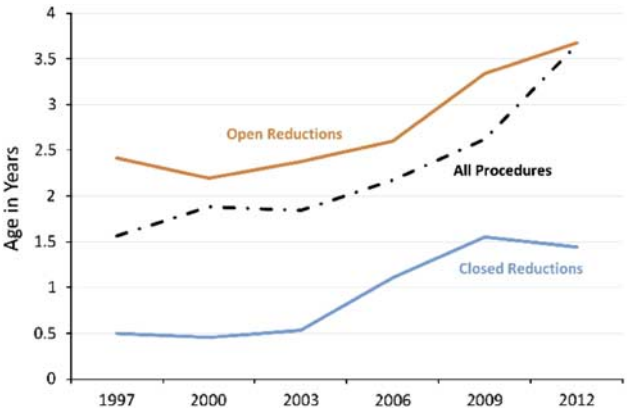

FIGURE 2. Mean patient age at time of procedure by year.

study period; comparing 1997 to 2012 data sets, the mean age at the time of surgery increased from 1.6 to 3.7 years ($P<0.001$). Mean age at open reduction increased from 2.4 to 3.3 years while mean age at closed reduction increased from 0.5 to 1.4 years (Fig. 2). The significant difference in age between reduction groups persisted across years ($P<0.001$).

Regional Variation

The Western region contributed the highest total number of operative reductions (Fig. 3). When examining regional differences for overall reductions using bivariate analysis, there was no significant difference found in sex ($P=0.07$) or mean age ($P=0.63$) of patients undergoing reduction. Types of insurance varied by region ($P<0.001$). The majority of patients were covered privately except for in the South, where Medicaid predominated. There was significant variability ($P<0.001$) in median income quartile and race for patients receiving reductions between regions. The majority of patients across regions were white except for the West, where more Hispanic patients underwent surgery; this was also seen for Mexican border states although these data were excluded from the overall analysis as state level information was not available in every KID data set; regional level information was available in all data set releases and was the basis for analysis. Operative reductions were predominantly performed in large urban teaching hospitals although the distribution of hospital type where reductions were performed varied between regions on bivariate analysis ($P<0.001$). Variability was found when comparing the proportion of closed versus open reductions within each region ($P=0.004$), with comparatively fewer open reductions in the Northeast (Fig. 4).

Multinomial regression confirmed the odds of having an open reduction was increased for patients from the Midwest [odds ratio (OR), 2.1; $P=0.003$], South (OR, 1.8; $P=0.005$), and West (OR, 1.8; $P=0.006$) compared with patients from the Northeast. Patients undergoing surgery in the Midwest had decreased odds of being Hispanic (OR, 0.5; $P=0.034$), and patients in the West had increased odds of being Hispanic and Asian/Pacific Islander (OR, 4.9; $P\leq0.001$ and OR, 2.8; $P=0.008$). Median income was

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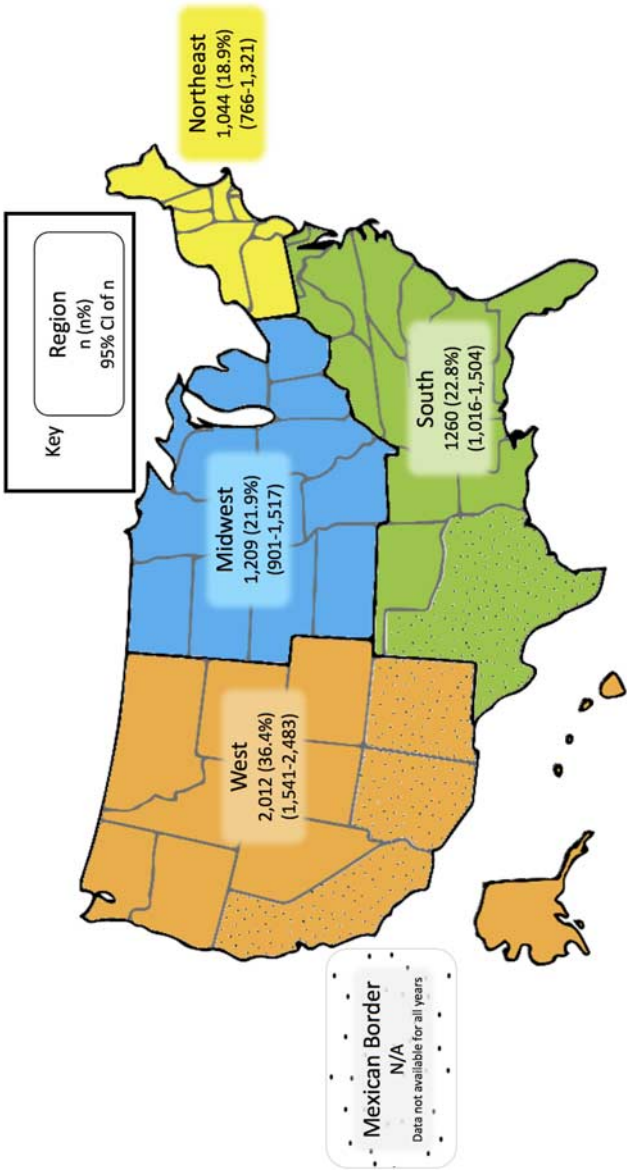

FIGURE 3. Regional distribution of total operative reductions. CI indicates confidence interval; N/A, not available.

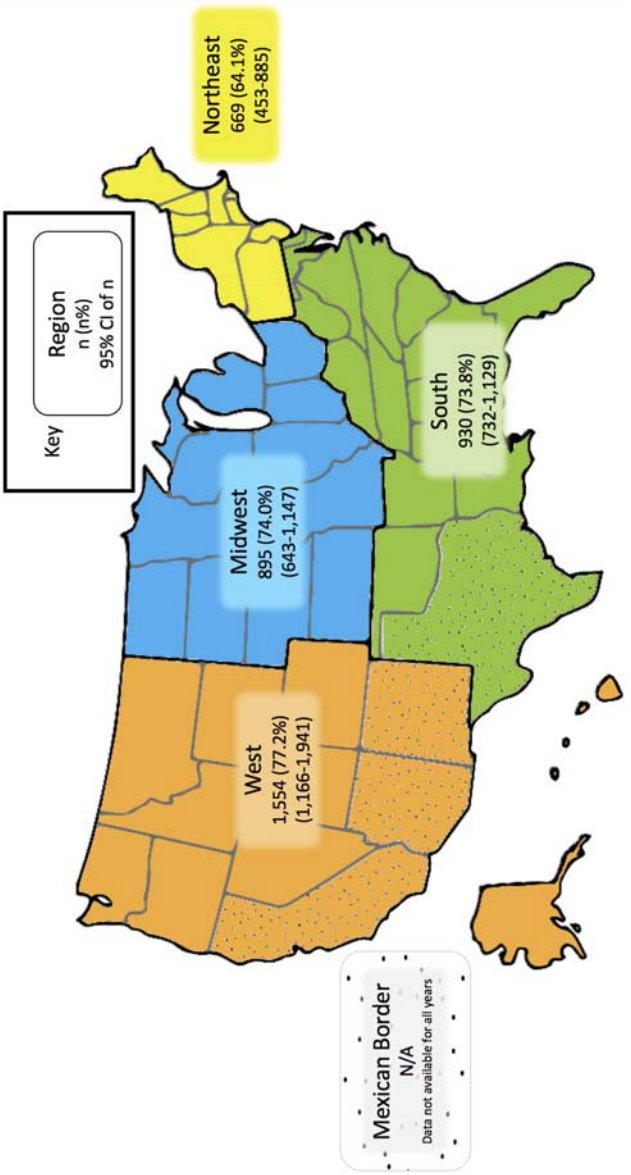

FIGURE 4. Regional distribution of open reductions only. CI indicates confidence interval; N/A, not available.

statistically associated with requiring surgery in the Midwest; the second lowest income quartile exhibited increased odds of operative reduction (OR, 1.9; $P = 0.009$) and the highest income quartiles showed decreased odds of reduction (OR, 0.5; $P = 0.018$). In the South, the highest income quartile had decreased relative odds of needing surgery (OR, 0.4; $P = 0.001$).

DISCUSSION

There are few recent epidemiologic studies on DDH in the United States; previous literature reports on the incidence of dislocations and subluxations[11–13] but has not focused on the epidemiology of surgical treatment. We believe valuable insight can be gained from examining patient and hospital characteristics associated with surgical disease, and the burden of surgical disease can help gauge successful case identification and nonoperative management.

In the United States, image-based screening for DDH in infants remains controversial with no universal standard for targeted ultrasound evaluation and insufficient evidence to support universal ultrasound screening according to many.[5] Before the publication of AAP guidelines in 2000, no formal guidelines existed on screening for DDH in the United States.[8] Subsequent guidelines have been endorsed by the Pediatric Orthopaedic Society of North America (POSNA) in 2007,[14] also advocating universal clinical screening. Most recently the American Academy of Orthopaedic Surgeons (AAOS) in 2014[15] released evidence-based guidelines

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endorsing a moderate strength recommendation against universal ultrasound screening. Assuming a stable incidence of DDH in the US population, if these guidelines have positively affected detection and early treatment of DDH we would anticipate a decrease in surgical reductions as early detection would improve the chances of successful nonoperative treatment.[16] In the present study, we noted an overall decrease in the number of operative reductions performed over time, but also a significant change in the proportion of closed versus open reductions, and an increased mean age of those children who did undergo surgery. The decrease in closed reductions could indicate a positive effect of national guidelines, with most mild cases being treated successfully with nonoperative means. However, the increasing age at time of procedural reduction for both open and closed may suggest more cases of late presentation and represent a potential area for improved screening practices. A multicenter analysis found that infants presenting later were more likely to have an irreducible hip dislocation,[12] which would require open reduction. Moreover, in a recent European review of 64 hips requiring open reduction, 71% were performed for patients presenting late, with only 40% detected by the universal clinical screening and targeted ultrasound utilized in the referral base.[17] The only patients who were treated with open reduction after early initiation of a Pavlik harness had bilateral involvement;[17] there may be a subset of infants with hip dislocations that will require open reduction regardless of early detection. However, bilateral involvement and other factors that may affect the success of early treatment such as laterality, initial reducibility of the hip, and Graf type[6] could not be assessed with this study design.

Socioeconomic risk factors have been previously explored in DDH; associations with both high and low socioeconomic status or no difference have been reported.[18] The socioeconomic proxies of insurance status and primary insurance payer in our sample showed the predominate insurance type to be private and almost equal representation of each income quartile respectively. On multivariate analysis, significant differences in income quartile between regions were seen only for the Midwest and South with a protective effect of higher income. The Midwest was the only region where lower income was associated with an increased likelihood of needing surgery. There may be variables we are unable to account for with the study design, such as access to care, that affects these findings. In addition, conclusions based on the income quartile data are limited due to a large number of patients not classified in the sample.

Differences in the incidence of DDH have been documented for different races,[1] although not examined extensively in the literature. A recent review of 424 DDH cases in Iowa found a predominantly white population. However, there was a higher than expected number of cases in Hispanic infants and a small but not insignificant proportion of cases in Black infants.[19] Our estimated population of DDH cases undergoing reduction nationally is also predominantly white. However, important geographic variations in the race were noted with a predominantly Hispanic population undergoing reductions in the West and in states along the Mexican Border. The Western region had the highest number of surgical reductions, increased odds of open reduction, and increased odds of reduction for Hispanic and Asian/Pacific Islanders. The Hispanic population accounted for over half the growth of the US population from 2000 to 2010, with 3 quarters of this population residing in the West or South.[20] In addition, the percentage of the US population that is foreign-born as defined by the US Census Bureau continues to increase, with 37% of the foreign-born population being from Central America (including Mexico) in 2010.[21] Our findings suggest that clinicians performing infant hip screening examinations should be cognizant of changing demographics in the United States, and particularly in the West and Mexican border states future investigation of targeted surveillance in Hispanic infants may be warranted.

We are limited in our ability to identify all variables that may influence the treatment of DDH due to the inpatient database survey design of this research. For example, rural birth location[22,23] and history of swaddling[24] are 2 nontraditional risk factors that have been identified for late-presenting DDH that were not included in our analysis. We are also unable to ascertain the impact of risk factors for late presentation on the increasing age of treatment observed. Age at initial presentation, prior treatment, and issues of physical access to health care, as well as surgeon treatment preferences and regional differences in philosophy with regard to timing of procedural reduction were also not measurable. For example, a meta-analysis from 2009 suggested higher grades of osteonecrosis were associated with reductions performed before the appearance of the femoral ossific nucleus[25] and this may have led certain surgeons to delay procedural reduction attempts during the time frame of this study. More recent meta-analyses, however, have refuted this finding.[26,27] We must also consider the possibility of misclassification and information bias with the use of a large administrative database. When creating the study population, patients with diagnoses of skeletal dysplasias may have not been excluded. However, these rare diagnoses are unlikely to have substantially altered the results. In addition, we are unable to estimate the cumulative incidence of reductions from our inpatient sample given the unknown size of the population with DDH at risk of undergoing reduction. Further, our discussion must acknowledge that the decrease in the number of operative reductions over time may reflect a change in the incidence of DDH. In commenting on screening effectiveness we are unable to determine whether national guidelines, particularly, that all infants receive thorough clinical screening regardless of risk factors, are being implemented appropriately, especially given the increasing age at the time of reduction observed.

CONCLUSIONS

This study is the first to our knowledge to present data on the recent surgical burden of DDH in the United States. There may be room for improvement in current screening and surveillance practices given our findings of an increasing proportion of surgeries being open and

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increasing age at procedure over time. Investigating how clinicians responsible for infant hip screening have or have not altered practice since the establishment of national guidelines may clarify these findings. More rigorous investigation of associations with socioeconomic factors, as well as research, education, and screening intervention particularly for Hispanic infants in the West and in states bordering Mexico may be worthwhile to reduce the burden of surgical disease in DDH.

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