Open and Closed Reduction for Developmental Dysplasia of the Hip in New York State

Incidence of Hip Reduction and Rates of Subsequent Surgery

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Background: There are limited data on the incidence and outcomes of open and closed hip reduction in patients with developmental dysplasia of the hip (DDH). The aims of this study were to determine the incidence of open and closed reduction of the hip using population-level data and to assess the rates of subsequent surgery.

Methods: Children aged 3 years and younger with DDH who underwent open or closed reduction of the hip between 1997 and 2013 were identified in the New York Statewide Planning and Research Cooperative System (SPARCS) database. Patient age, sex, race, and insurance status as well as concurrent procedures were extracted. Admissions through 2014 were searched for subsequent surgeries, providing a minimum 1-year post-reduction surveillance for all patients. Age-specific incidence rates were calculated using New York State annual population data. The rates of concurrent and subsequent surgeries were calculated. A sensitivity analysis was performed to provide a range for the rates of subsequent surgery. Univariate analyses consisted of chi-square or Fisher exact tests for categorical variables.

Results: In total, 897 patients (637 who underwent closed reduction and 260 who underwent open reduction) were identified. The age-specific incidence per 100,000 population was 12.5 for closed reduction and 2.6 for open reduction for <1-year-olds, 2.2 for both closed and open reductions for 1-year-olds, 0.4 for closed reduction and 1.0 for open reduction for 2-year-olds, and <0.3 for closed reduction and 0.5 for open reduction for 3-year-olds. Overall, closed reductions were performed more frequently over the study period (p < 0.01). The estimated rate of subsequent ipsilateral surgery was 12.4% (range, 9.4% to 33.1%) after index closed reduction and was 14.2% (range, 8.5% to 40.1%) after index open reduction.

Conclusions: We found that the incidence of closed or open hip reduction for DDH was small and that there was an increase in the number of closed reductions performed over time. The rates of subsequent surgery remained relatively high for patients after index closed or open hip reduction.

Level of Evidence: Therapeutic Level III. See Instructions for Authors for a complete description of levels of evidence.

Developmental dysplasia of the hip (DDH) encompasses a spectrum of abnormal hip development in utero or in the perinatal period. DDH can range from mild dysplasia of the acetabulum to irreducible dislocation of the hip, and its clinical features depend on several factors, including the age of the child, the severity of the abnormality, and whether there is unilateral or bilateral involvement. When DDH is detected at an early age, the treatment is often more successful, with improved long-term outcomes. In the first 6 months of life, DDH is most commonly treated with use of a brace or harness, with successful treatment in 70% to 95% of cases. In older children, the Pavlik harness has a lower success rate, and it has been associated with a higher risk of osteonecrosis of the femoral head. As a result, patients in whom treatment with a brace fails or who present at ≥6 months of age are often treated with closed or open reduction of the hip under general anesthesia. Closed reduction of the hip is usually performed in younger children. Open reduction of the hip is traditionally reserved for patients in whom closed reduction has failed, who present late, or who have a fixed or teratologic dislocation.

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The rates of closed and open hip reductions in the infant and toddler years have not been clearly identified, nor has the rate of subsequent surgery after hip reduction. The primary aim of the current study was to determine the incidence of open and closed reductions of the hip. The secondary aim of this study was to determine the rates of subsequent surgery after index closed and open reductions of the hip.

**Materials and Methods**

Infants and young children from birth to age 3 years (inclusive) who underwent closed or open reduction of the hip for DDH between 1997 and 2013 were identified in the New York Statewide Planning and Research Cooperative System (SPARCS) database. SPARCS contains a census of all hospital admissions and cases of ambulatory surgery performed in New York State, with the exception of cases performed in federal hospitals (e.g., Veterans Affairs or other military hospitals, or penitentiaries). This data set includes surgeries performed by every surgeon and on every patient in New York State, provided they were performed in nonfederal hospitals. Admissions through 2014 were searched to identify subsequent surgeries, providing a minimum 1-year post-reduction surveillance for each patient. The median surveillance duration was 110 months (range, 12 to 215 months). Patients residing outside of New York State were excluded, as it was hypothesized that these patients may be more likely to have follow-up in their home state, and thus subsequent surgeries for these patients were less likely to be captured in this longitudinal database. Similar methodology using the SPARCS database has been used in other studies.

Cases of closed or open reduction were identified by International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) procedure codes for inpatient procedures and Current Procedural Terminology, Fourth Edition (CPT-4) procedure codes for ambulatory surgery procedures. Only patients with a concurrent diagnosis code for DDH were included, while patients also having a neurologic or spinal cord or syndromic diagnosis code were excluded. Patients who had a hip procedure prior to the index (i.e., first) reduction were also excluded. ICD-9-CM procedure codes and CPT-4 procedure codes were also used to identify concurrent hip procedures as well as subsequent hip surgery after the index reduction. The concurrent and subsequent procedures of interest included subsequent closed hip reduction, subsequent open hip reduction, pelvic osteotomy, femoral osteotomy, and other hip procedures. Appendix A lists all ICD-9-CM and CPT-4 codes used to classify diagnoses and procedures of interest for this study.

Inpatient procedures were classified as bilateral when the procedure was recorded for a given patient more than once on the same day; otherwise, the procedure was considered unilateral. Ambulatory surgery procedures were classified as bilateral, right or left, according to the recorded CPT modifier when present, and unilateral otherwise. Because of the high number of cases for which the index reduction or subsequent surgery was classified as unilateral (i.e., laterality was not recorded for at least 1 procedure), estimates of subsequent ipsilateral procedures were calculated using 3 scenarios: (1) subsequent procedures performed ≤21 days of the index hip reduction were classified as ipsilateral, and procedures performed >21 days after the initial reduction were classified as contralateral procedures, (2) any subsequent procedure was considered to be contralateral to the index hip reduction, and (3) any subsequent procedure was considered to be ipsilateral to the index hip reduction (Fig. 1). For analyses of subsequent procedures, we report Scenario 1 because it most accurately reflects clinical practice, and we include Scenarios 2 and 3 as ranges representing the best and worst-case scenarios, respectively.

Patient characteristics from SPARCS included in the analytic data sets were month and year of birth, sex, race (white,
black, other, unknown), and insurance status (Medicaid versus all other payers). The incidence per 100,000 population by year of age (<1, 1, 2, and 3) for open and closed reductions was calculated using annual population estimates from 1997 to 2013, obtained from the New York State Department of Health Vital Statistics. Age in months at the time of the index reduction was calculated by subtracting the month and year of birth from the month and year of the reduction admission. Patient ZIP code-level poverty prevalence was obtained from the 2000 Census data and dichotomized as >20% or ≤20%, which represents the 75th percentile of poverty prevalence in the study population.

Statistical Analysis

Univariate analyses consisted of chi-square or Fisher exact tests for categorical variables. The rates of subsequent closed reduction, open reduction, pelvic osteotomy, femoral osteotomy, and other hip procedures are presented for each type of reduction based on Scenario 1 (ipsilateral if ≤21 days and contralateral if >21 days), with the range representing Scenarios 2 (all contralateral) and 3 (all ipsilateral). Kendall tau-b correlation coefficients were calculated to examine trends over time. Statistical analysis was performed using SAS software (version 9.4; SAS Institute), with the significance level set at 0.05.

Results

Incidence of Closed and Open Hip Reduction

From 1997 to 2013, there were 897 patients aged 0 to 3 years (inclusive) who underwent closed reduction (637 patients) or open reduction (260 patients) (Table I). The age-specific incidence per 100,000 population was 12.5 for closed reduction and 2.6 for open reduction for <1-year-olds, 2.2 for closed reduction and 2.2 for open reduction for 1-year-olds, 0.4 for closed reduction and 1.0 for open reduction for 2-year-olds, and <0.3 for closed reduction and 0.5 for open reduction for 3-year-olds. The incidence of closed reduction appeared to increase slightly over time (Kendall tau-b, 0.32; p = 0.070), while the incidence of open reduction was stable (Kendall tau-b, −0.10; p = 0.564) (Fig. 2). Overall, closed reductions were performed more frequently over the study period (p < 0.01). The median age at the index closed reduction was 6 months (range, 0 to 47 months), while the median age at open reduction was 16 months (range, 1 to 48 months).

Subsequent Surgery After Index Hip Reduction

The rate of any subsequent ipsilateral surgery after the index closed reduction was 12.4% (range, 9.4% to 33.1%), and the rate of any subsequent ipsilateral surgery after the index open

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**TABLE I** Demographics and Surgical Details for Open and Closed Hip Reduction Among Children with DDH ≤3 Years of Age in New York State

|                          | Closed Reduction | Open Reduction | P Value |
|--------------------------|------------------|----------------|---------|
|                          | No. of Patients  | %*             | No. of Patients | %* |         |
| Total                    | 637              | 71.0           | 260              | 29.0 | <0.001  |
| Age in yr                |                  |                |                   |     |         |
| 0                        | 523              | 82.1           | 107              | 41.2 |         |
| 1                        | 91               | 14.3           | 92               | 35.4 |         |
| 2                        | †                | †              | 40               | 15.4 |         |
| 3                        | †                | †              | 21               | 8.1  |         |
| Sex                      |                  |                |                   |     | 0.001   |
| Female                   | 532              | 83.5           | 193              | 74.2 |         |
| Male                     | 105              | 16.5           | 67               | 25.8 |         |
| Race                     |                  |                |                   |     | 0.035   |
| White                    | 386              | 60.6           | 149              | 57.3 |         |
| Black                    | 27               | 4.2            | 24               | 9.2  |         |
| Other                    | 183              | 28.7           | 72               | 27.7 |         |
| Unknown                  | 41               | 6.4            | 15               | 5.8  |         |
| Insurance                |                  |                |                   |     | 0.205   |
| Medicaid                 | 267              | 41.9           | 121              | 46.5 |         |
| All others               | 370              | 58.1           | 139              | 53.5 |         |
| Poverty rate             |                  |                |                   |     | 0.033   |
| ZIP code poverty prevalence >20% | 152 | 23.9  | 84              | 32.3 |         |
| Concurrent procedures    |                  |                |                   |     |         |
| Femoral osteotomy        | †                | †              | 71               | 27.3 | <0.001  |
| Pelvic osteotomy         | †                | †              | 45               | 17.3 | <0.001  |

*The percentages shown for the “Total” row are of the total number of patients (n = 897). All other percentages are of the given group (n = 637 for closed and n = 260 for open reduction). †Results and derivatives where cell counts are <11 have been redacted to comply with SPARCS small-cell-size policies.*
reduction was 14.2% (range, 8.5% to 40.1%). Patient characteristics are summarized by subsequent surgery status in Table II.

Among patients who underwent an index closed reduction, the rate of subsequent repeat closed reduction was 8.8% (range, 7.4% to 20.3%), and the rate of subsequent open reduction was 4.7% (range, 2.7% to 12.1%). The rate of subsequent femoral osteotomy among these patients was 2.0% (range, <1.7% to 6.8%), and the rate of subsequent pelvic osteotomy was <1.7% (range, <1.7% to 8.0%). For patients who underwent an index open reduction, the rate of repeat open reduction was 5.4% (range, <4.2% to 19.6%). The rate of subsequent femoral osteotomy after an index open reduction was 5.8% (range, 5.0% to 20.4%), and the rate of subsequent pelvic osteotomy was <4.2% (range, <4.2% to 11.9%). The estimated rates of ipsilateral procedures for all surgery categories and scenarios by type of index reduction are presented in Tables III and IV.

**Discussion**

The aims of this study were to determine the population-level incidence of open and closed reduction of the hip in infants and young children with DDH, and to assess the rates of subsequent ipsilateral surgery after the index hip reduction. The incidence of closed hip reduction in the first year of life was 12.5 per 100,000, and for open reduction, it was 2.6 per 100,000. Incidence decreased over the subsequent years; at the age of 3, there was <1 reduction procedure per 100,000 for both closed and open reductions. The median patient age for closed reduction was 6 months, and the median age for open reduction was 16 months. Annual trends showed that the type of reduction changed over the 17-year study period, with more closed than open reductions being performed over time. This trend was due to an increase in closed reductions, as the rates of open reductions remained relatively constant. The reasons for the increase in closed reductions are

| TABLE II Characteristics of Patients with or without Any Subsequent Hip Procedure |
|---------------------------------------------------------------|
| Subsequent Procedure | Yes | No |
|----------------------|-----|----|
| Index reduction type |     |    |
| Closed               | 214 | 423|
| Open                 | 106 | 154|
| Age in yr            |     |    |
| 0                    | 206 | 424|
| 1                    | 76  | 107|
| 2                    | 25  | 33 |
| 3                    | 13  | 13 |
| Sex                  |     |    |
| Female               | 248 | 477|
| Male                 | 72  | 100|
| Race                 |     |    |
| White                | 179 | 356|
| Black                | 15  | 36 |
| Other                | 109 | 146|
| Unknown              | 17  | 39 |
| Insurance            |     |    |
| Medicaid             | 157 | 231|
| All others           | 163 | 346|
| Poverty rate         |     |    |
| ZIP code poverty     |     |    |
| prevalence >20%      | 87  | 149|

*The percentages are of the total number of patients with (n = 320) or without (n = 577) any subsequent procedure.
unclear, but may be secondary to increased awareness and earlier diagnosis of DDH, or the implementation of screening programs11.

There is a paucity of literature on the epidemiology of open and closed reduction for DDH. A recent study by Nelson et al. using the Healthcare Cost and Utilization Project Kids’ Inpatient Database (KID) found a decrease in the frequency of closed reduction compared with open reduction over time, and reported a mean age of 0.8 year at the time of closed reduction and a mean age of 2.8 years at the time of open reduction12. We found a different trend in our population, with an increase in the frequency of closed reductions over time and younger median age at the time of open and closed reductions. These differences may be due to the fact that Nelson et al. averaged national data12, whereas we focused on trends and practice in New York State. Chang et al. reported an average age of 1.7 years at the time of reduction in a Taiwanese population; however, the authors did not distinguish between types of reduction14. In general, this is the first study to our knowledge to show state-level data regarding the incidence of hip reductions in the infant and toddler years. Assuming that all children identified with a hip dislocation undergo reduction in a timely manner, these data can be used as a proxy for the need for index reduction for DDH, with a total incidence of 5.4 per 100,000 in the first 4 years of life.

Up to one-third of the patients who underwent an index closed reduction underwent a subsequent ipsilateral surgery, and up to 12% of the patients initially treated with a closed reduction underwent a subsequent open reduction. In comparison, up to 40% of the patients who underwent an index open reduction needed a subsequent ipsilateral surgery. The most common procedures following open or closed hip reduction are pelvic and femoral osteotomies. Previous studies have found reoperation rates ranging from 25% to 74% after index open and closed reduction, but they have been limited to smaller sample sizes and single institutions8. The lack of documented laterality is a notable limitation of database studies, and in the current study, we performed a sensitivity analysis of the best and worst-case scenarios. We report a range

TABLE III Rate of Subsequent Ipsilateral Procedures in Patients Having Index Closed Reduction (N = 637)

| Subsequent Procedure | Scenario* |  |  |  |
|----------------------|-----------|----------------|----------------|----------------|
|                      | No. | %  | No. | %  | No. | %  |
| Any ipsilateral procedure | 79  | 12.4 | 60  | 9.4 | 211 | 33.1 |
| Open reduction       | 30  | 4.7 | 17  | 2.7 | 77  | 12.1 |
| Closed reduction      | 56  | 8.8 | 47  | 7.4 | 129 | 20.3 |
| Femoral osteotomy    | 13  | 2.0 | †   | †   | 43  | 6.8  |
| Pelvic osteotomy     | †   | †   | †   | †   | 51  | 8.0  |

*Scenario 1 = procedures without known laterality classified as ipsilateral if ≤21 days of the index reduction and contralateral if >21 days. Scenario 2 = all unknown laterality procedures classified as contralateral. Scenario 3 = all unknown laterality procedures classified as ipsilateral. †Results and derivatives where cell counts are <11 have been redacted to comply with SPARCS small-cell-size policies.

TABLE IV Rate of Subsequent Ipsilateral Procedures in Patients Having Index Open Reduction (N = 260)

| Subsequent Procedure | Scenario* |  |  |  |
|----------------------|-----------|----------------|----------------|----------------|
|                      | No. | %  | No. | %  | No. | %  |
| Any procedure        | 37  | 14.2 | 22  | 8.5 | 106 | 40.8 |
| Open reduction       | 14  | 5.4 | †   | †   | 51  | 19.6 |
| Femoral osteotomy    | 15  | 5.8 | 13  | 5.0 | 53  | 20.4 |
| Pelvic osteotomy     | †   | †   | †   | †   | 31  | 11.9 |

*Scenario 1 = procedures without known laterality classified as ipsilateral if ≤21 days of index reduction and contralateral if >21 days. Scenario 2 = all unknown laterality procedures classified as contralateral. Scenario 3 = all unknown laterality procedures classified as ipsilateral. †Results and derivatives where cell counts are <11 have been redacted to comply with SPARCS small-cell-size policies.
after an index open reduction. These data help to set expectations that are aligned with actual clinical outcomes. While the results of this study are illuminating, data from large prospective registries are necessary to confirm the findings of this study and to determine the burden of disease for DDH in other populations.

Appendix

Supporting material provided by the authors is posted with the online version of this article as a data supplement at jbjs.org (http://links.lww.com/JBJSOA/A142).

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