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Persistence and Extent of Neonatal Brachial Plexus Palsy: Association with Number of Maneuvers and Duration of Shoulder Dystocia

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Abstract

Objective The main objective of this article is to determine if persistence of neonatal brachial plexus palsy (NBPP) following shoulder dystocia was associated with maneuvers used or duration of impacted shoulder.

Study Design Retrospective review of children with NBPP and documented shoulder dystocia. Student *t*-tests and chi-squared tests were used to compare outcomes when shoulder dystocia resolved with >3 versus ≤ 3 maneuvers or duration $>$ versus ≤ 120 seconds. Relative risk (RR) with 95% confidence intervals (CI) was calculated.

Results Among 46 children with NBPP and shoulder dystocia, incidence of persistence was significantly higher at 2 years of age when >3 versus ≤ 3 maneuvers were used (100 vs. 62%; RR: 1.6, 95% CI: 1.2–2.2). When resolution of impacted shoulder lasted >120 versus ≤ 120 seconds, NBPP at 2 years was significantly more likely (100 vs. 63%; RR: 1.6, 95% CI: 1.1–2.2). Injury to all five nerves of the brachial plexus was more likely if standard deviation lasted >120 versus ≤ 120 seconds (RR: 2.2; 95% CI: 1.03–4.6).

Conclusion Though the number of maneuvers used and duration of shoulder dystocia are associated with persistence of NBPP, the retrospective nature of the study of a selective cohort precludes recommendations changing the current management of shoulder dystocia.

Keywords
- neonatal brachial plexus palsy
- shoulder dystocia

Persistent neonatal brachial plexus palsy (NBPP), defined as deviation of a joint's active range of motion from normal by >10 degrees and/or musculoskeletal contractures at 1 year or greater, occurs in ~1 to 2 per 10,000 live births.[1,2] Children with persistent palsy are at risk of multiple sequelae, and are likely to undergo surgical procedures.[3–11] The estimated societal cost of persistent palsy is 1 to 3 billion dollars annually.[12] To potentially mitigate the sequelae of palsy, an improved understanding of the antecedent events is warranted.

Shoulder dystocia is the inability to deliver shoulders with gentle downward traction on the head, requiring additional maneuvers to effectuate delivery.[13] Although NBPP can occur without shoulder dystocia,[14–16] it is a risk factor for palsy.[1,17,18] Prior reports linking impacted shoulder with NBPP had several shortcomings: small sample size,[19] inadequate description of whether the palsy is transient or persistent,[20] incongruent review of charts, and/or inadequate description of management of injury by a multidisciplinary team.[17,21] To

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overcome these shortcomings, we undertook this retrospective study of children with NBPP.

The objective of the retrospective study was to determine a link, if any, between the numbers of maneuvers used to relieve the shoulder dystocia or the duration of impacted shoulder with severity and extent of persistent NBPP. We hypothesized that persistence of NBPP and higher Narakas grade (number of nerve roots injured) are more common when more maneuvers were used to relieve shoulder dystocia or if the shoulder dystocia had longer duration.[22,23]

Materials and Methods

From 2004 to 2016, children who were treated at the University of Michigan Brachial Plexus and Peripheral Nerve Program (UM-BP/PN Program) with the diagnosis of NBPP and accessible obstetric records (antepartum, intrapartum, and postpartum from the hospital where the delivery occurred) without prior surgery for NBPP were included. Referrals come from Michigan and adjacent states, and children may have had nonsurgical treatment prior to referral. Inclusion criteria were nonanomalous, singletons, for whom maternal and/or perinatal records documented maneuvers used to resolve shoulder dystocia and its duration. Exclusion criteria were cesarean deliveries. The study was approved by the Institutional Review Board at University of Michigan.

To determine persistence of NBPP, children with NBPP were evaluated by the interdisciplinary faculty and staff of UM-BP/PN Program, inclusive of ancillary testing such as electrodiagnostics and imaging. NBPP extent was classified as upper/upper-middle (Narakas I–II) and total NBPP (Narakas III–IV). Upper NBPP represents nerve injury to C5 and C6 (upper), which affects deltoid and bicep functions, while wrist and hand functions remain intact, and upper-middle NBPP represents injury to C7 as well that additionally affects elbow and wrist extension. Total NBPP affects C5, C6, C7, C8, and T1 nerve roots and presents with a flail arm with (Narakas IV) or without (Narakas III) Horner syndrome. NBPP was considered persistent at 1 and 2 years of age if musculoskeletal contractures were present or if any joint's active range of motion deviated from normal by >10 degrees.

An obstetric team comprising a maternal–fetal medicine (MFM) subspecialist, an MFM fellow, and a resident reviewed all of the prenatal and peripartum records. None of the members of the obstetric team were involved in any of the deliveries. The UM-BP/PN Program team did not review the obstetric chart. Data regarding maternal demographics, medical, and obstetric complications was culled, along with the intrapartum events. The obstetric team determined if shoulder dystocia complicated the delivery by reviewing the clinicians'—physician, midwives, nurses—notes and any institutional forms a hospital may use to describe a shoulder dystocia. The team determined whether shoulder dystocia occurred, the number of maneuvers used, and the duration of shoulder dystocia, without being aware of the extent or persistence of NBPP.

Normal Q–Q plots were conducted to ensure the normality of the data distribution. To investigate the associations of management of shoulder dystocia with extent of NBPP, Student *t*-tests were used for continuous variables and chi-squared tests were conducted for categorical variables. Using Stata version 13.1 (College Station, TX), unadjusted relative risk (RR) with 95% confidence intervals (CI) was calculated for comparisons of those whose shoulder dystocia resolved with $\leq$ versus >3 maneuvers and those that persisted for $\leq$ versus >120 seconds. A p-value <0.05 or 95% CI not crossing integer 1 was considered statistically significant.

Results

During the study period, 106 charts of mother–children with NBPP and documented shoulder dystocia were reviewed. Data regarding the maneuvers used to manage the shoulder dystocia were available in 44% (46/106) of children with NBPP. Shoulder dystocia resolved with ≤ 3 maneuvers in 85% (39/46) of cases. The maternal demographics—age, ethnicity, nulliparity, body mass index (BMI) ≥ 30 kg / m^2 at delivery, diabetic status—did not differ among women whose shoulder dystocia was relieved with ≤ 3 compared with those that required >3 maneuvers. The rate of induction and usage of vacuum or forceps were similar in the two groups, as was whether the newborn was macrosomic (birth weight of 4,000 g or more). Rotational maneuvers (Woods Screw or Rubin) and extraction of the posterior arm were significantly more common among children with NBPP whose standard deviation was relieved with >3 maneuvers, as compared with three or less. The likelihood of third or fourth degree perineal laceration was similar for the two groups (►**Table 1**).

Gender, rate of macrosomia, Apgar score ≤ 5 at 5 minutes, and fracture or bruising noted at delivery were similar among children whose shoulder dystocia was resolved with $\leq$ versus >3 maneuvers. The persistence of NBPP at 1 year (RR: 1.44; 95% CI: 1.1–1.9) and at 2 years (RR: 1.60; 95% CI: 1.2–2.2) was significantly higher among children whose shoulder was resolved with $>$ versus ≤ 3 maneuvers. The Narakas score III or IV—all five brachial plexus nerves injured—was similar in the two groups (►**Table 2**).

The duration of shoulder dystocia was documented in 43 cases, with the impacted shoulder was resolved in ≤ 120 seconds in 81% of cases. Among children with NBPP whose shoulder dystocia resolved in $\leq$ versus >120 seconds, the maternal demographics were similar for maternal age, ethnicity, nulliparity, and BMI ≥ 30 kg/m^2 at delivery. The rate of induction was significantly higher among children with NBPP whose shoulder dystocia lasted >120 seconds ($p=0.04$). Among the various maneuvers used to relieve the shoulder dystocia, only the rotational (Woods Screw or Rubin maneuvers) differed significantly among those with impacted shoulder dystocia $\leq$ versus >120 seconds (39 vs. 88%; $p=0.04$). The rate of third or fourth degree perineal laceration was similar between the two groups (►**Table 3**).

Gender, rate of macrosomia, Apgar score ≤ 5 at 5 minutes, and fracture or bruising noted at delivery were similar among children whose shoulder dystocia was resolved with $\leq$ versus >120 seconds. The persistence of NBPP at 1 year (RR: 1.38; 95% CI: 1.1–1.8) and at 2 years (RR: 1.58; 95% CI:

Table 1 Maternal and intrapartum characteristics of children with neonatal brachial plexus palsy subsequent shoulder dystocia

	Shoulder dystocia resolved with ≤ 3 maneuvers ($n = 39$)	Shoulder dystocia resolved with > 3 maneuvers ($n = 7$)	*p*-Value
Age at delivery (y)			
< 20	1/38 (3%)	0/7	0.47
≥ 35	6/38 (16%)	0/7	
Ethnicity			
African-American	7/39 (18%)	1/7 (14%)	0.80
Caucasian	31/39 (79%)	6/7 (86%)	
Other	1/39 (3%)	0	
Nulliparous	16/39 (41%)	5/7 (71%)	0.14
Maternal BMI at delivery			
≥ 30 (kg/m^2)	15/18 (83%)	1/2 (50%)	0.26
Diabetes[a]	8/39 (21%)	1/7 (14%)	0.72
Induction	22/39 (56%)	5/7 (71%)	0.42
Vacuum or forceps	8/39 (21%)	0/7	0.23
Maneuvers used to relieve shoulder dystocia			
McRoberts	35/39 (90%)	7/7 (100%)	0.99
Suprapubic pressure	28/39 (72%)	7/7 (100%)	0.17
Rotational maneuvers[b]	14/39 (36%)	7/7 (100%)	**0.001**
Delivery of posterior arm	16/39 (41%)	7/7 (100%)	**0.009**
Zavanelli	0/39 (0%)	1/7 (14%)	0.15
Perineal laceration			
No laceration	24/36 (67%)	5/7 (71%)	0.77
First or second degree	9/36 (25%)	1/7 (14%)	
Third or fourth degree	3/36 (8%)	1/7 (14%)	

Abbreviation: BMI, body mass index.
Data presented as *n* (%).
[a]Diabetes before or during pregnancy.
[b]Woods Screw or Rubin maneuvers.
Chi-squared test was applied for group comparisons.
Bolded if significantly different.

1.1–2.2) was significantly higher among children whose shoulder dystocia was resolved with $\leq$ versus $>$ 120 seconds. Lastly, the Narakas score III or IV—all five brachial plexus nerves injured—was significantly higher if shoulder dystocia lasted $>$ 120 seconds (RR: 2.19; 95% CI: 1.03–4.6; ►**Table 4**).

Discussion

The main findings of our study are that among children with NBPP subsequent to shoulder dystocia, the persistence of brachial plexus palsy is associated with numbers of maneuvers utilized ($>$ 3) and duration of impacted shoulder ($>$ 120 seconds). This was true at both 1 and 2 years of life for those with persistence of NBPP. Additionally, the brachial plexus injury involving all five nerves is more likely to be associated with duration of shoulder dystocia being $>$ 120 seconds versus $\leq$ 120 seconds, and is not associated with number of maneuvers.

Previous publications have reported that the number of maneuvers used and the duration of shoulder dystocia were related to neonatal injury. Hoffman et al, for example, noted that among 2,018 cases of shoulder dystocia, the overall rate of neonatal injury was 5.2% and it was significantly related to total number of maneuvers performed. The rate of injury was ~5% with 1 maneuver and over 15% if 4 maneuvers were used. The investigators also reported that rotational maneuvers were associated with neonatal injury.[24] Leung et al noted that 95% of shoulder dystocia are resolved with 3 or fewer maneuvers and that the injury to the newborn is highest with 4 or more maneuvers.[23] Neither of these publications had follow-up on these newborns and were therefore unable to remark on P-NBPP.

Our findings differ from other publications on the topic in three important ways. First, prior publications on children with NBPP often relied on parents' recall of obstetric events,[14,16,25] which may be biased. Second, prior reports

Table 2 Children with neonatal brachial plexus palsy subsequent to shoulder dystocia

	Shoulder dystocia resolved with ≤ 3 maneuvers ($n = 39$)	Shoulder dystocia resolved with > 3 maneuvers ($n = 7$)	RR (95% CI)
Gender			
Female	18/39 (46%)	5/7 (71%)	0.24
Birth weight (g)			
$\geq 4{,}000$	21/39 (54%)	4/7 (57%)	0.87
Apgar score ≤ 5 at 5 min	5/39 (13%)	0/7	0.47 (0.03–7.6)
Fracture at delivery	5/36 (14%)	1/7 (14%)	1.06 (0.1–7.7)
Humerus	2/36 (6%)	1/7 (14%)	
Clavicle	3/36 (8%)	0	
Both	0	0	
Bruising at delivery	8/33 (24%)	2/6 (33%)	1.42 (0.4–5.1)
Face	5/33 (15%)	1/6 (17%)	
Scalp	1/33 (3%)	0	
Extremity	4/32 (13%)	0	
Chest	1/32 (3%)	1/6 (17%)	
Status of NBPP at 1 y			
Resolved NBPP	8/26 (31%)	0	**1.44 (1.1–1.9)**
Persistent NBPP	18/26 (69%)	5/5(100%)	
Status of NBPP at 2 y			
Resolved NBPP	9/24 (38%)	0	**1.60 (1.2–2.2)**
Persistent NBPP	15/24 (62%)	3/3 (100%)	
Narakas score III–IV[a]	14/39 (36%)	3/7 (43%)	1.22 (0.5–3.2)

Abbreviations: CI, confidence interval; NBPP, neonatal brachial plexus palsy; RR, relative risk.
Data presented as *n* (%).
[a]Narakas III–IV: all five nerves injured.
Bolded if significantly different.

linking shoulder dystocia with NBPP did not have children evaluated in a consistent manner.[17,18,21] Thus, associations between severity of shoulder dystocia and extent of brachial plexuses injury are possibly erroneous. Third, in our study, clinicians evaluating the obstetric course were blinded to the extent of neurological injury to the child, and the neurosurgical team was blinded to the obstetric data. Despite these strengths, due to the retrospective nature of our analysis, causation between number of maneuvers utilized or duration of shoulder dystocia and persistence of NBPP should be avoided. Additionally, our results do not suggest that clinicians should change the management of shoulder dystocia, that is, avoid using > 3 maneuvers when necessary or artificially curtail the duration of impacted shoulder to ≤ 120 seconds. Rather, our study may provide insight in counseling patients and parents on outcomes following a shoulder dystocia.

The limitations of our study should be acknowledged. The sample size is small: < 50 cases of P-NBPP. Nevertheless, considering persistent NBPP occurs in 1 to 2 per 10,000 live births (21), ~250,000 to 500,000 deliveries had to have occurred to allow analysis of 47 cases of NBPP. Documentation about management of the shoulder dystocia was described in only about half of the children with NBPP, which is acknowledged as a shortcoming on the topic.[26] Another limitation of the study is that these children were being followed by a multidisciplinary clinic after referral, which may have changed prognosis and inherent bias due to the selected cohort. Thus, our findings may not be applicable to cohorts that are not followed in such a prescribed manner.[27] The categorization of the two exposures may seem arbitrary, though it was based on prior publications[17,24] and small sample size. Lastly, the duration of shoulder dystocia should be considered as an estimate for we do not have evidence that when measured it was done consistently and accurately.

In conclusion, among children with persistent NBPP that had documented shoulder dystocia, the persistence at 1 and 2 years of age is associated with utilization of > 3 maneuvers. Additionally, shoulder dystocia that resolved with duration of > 120 seconds is also associated with higher rates of persistent brachial plexus palsy at both 1 and 2 years of age. Lastly, the risk of injuring all five nerve roots (Narakas grade III and IV) of the brachial plexus is higher when resolution of shoulder dystocia exceeds 120 seconds.

Table 3 Maternal and intrapartum characteristics of children with neonatal brachial plexus palsy subsequent shoulder dystocia

	Duration of shoulder dystocia $\leq$ 120 s ($n = 35$)	Duration of shoulder dystocia $>$ 120 s ($n = 8$)	*p*-Value
Age at delivery (y)			
$<$ 20	1/35 (3%)	0/7	0.37
$\geq$ 35	7/35 (20%)	0/7	
Ethnicity			
African-American	4/35 (11%)	3/8 (38%)	0.34
Caucasian	29/35 (83%)	5/8 (62%)	
Other	2/35 (6%)	0	
Nulliparous	15/35 (43%)	3/8 (38%)	0.78
Maternal BMI at delivery			
$\geq$ 30	8/10 (80%)	4/4 (100%)	0.33
Diabetes[a]	8/33 (24%)	1/8 (13%)	0.47
Induction	14/30 (47%)	7/8 (88%)	**0.04**
Vacuum or forceps	5/33 (15%)	0/8	0.24
Maneuvers used to relieve shoulder dystocia			
McRoberts	28/29 (97%)	7/8 (88%)	0.39
Suprapubic pressure	24/29 (83%)	6/8 (75%)	0.63
Rotational maneuvers[b]	11/28 (39%)	7/8 (88%)	**0.04**
Delivery of posterior arm	13/28 (46%)	7/8 (88%)	0.05
Zavanelli	0/28 (0%)	1/8 (13%)	0.22
Perineal laceration			
No laceration	21/29 (72%)	5/7 (71%)	0.78
First or second degree	6/29 (21%)	1/7 (14%)	
Third or fourth degree	2/29 (7%)	1/7 (14%)	

Abbreviation: BMI, body mass index (kg/m^2).
Data presented as *n* (%); Chi-squared test was applied for group comparisons.
[a]Diabetes before or during pregnancy.
[b]Woods Screw or Rubin maneuvers.
Bolded if significantly different.

Table 4 Children with neonatal brachial plexus palsy subsequent to shoulder dystocia

	Duration of shoulder dystocia $\leq$ 120 s ($n = 35$)	Duration of shoulder dystocia $>$ 120 s ($n = 8$)	RR (95% CI)
Gender			
Female	15/35 (43%)	3/8 (38%)	0.78
Birth weight (g)			
$\geq$ 4,000	16/33 (48%)	6/8 (75%)	0.18
Apgar score $\leq$ 5 at 5 min	4/35 (11%)	1/8 (13%)	1.09 (0.1–8.5)
Fracture at delivery	5/33 (15%)	0/8	0.34 (0.02–5.6)
Humerus	2/33 (6%)	0	
Clavicle	3/33 (9%)	0	
Both	0	0	
Bruising at delivery	6/31 (19%)	3/6 (50%)	2.58 (0.9–7.6)
Face	4/31 (13%)	2/6 (33%)	

Table 4 (*Continued*)

	Duration of shoulder dystocia ≤ 120 s ($n = 35$)	Duration of shoulder dystocia > 120 s ($n = 8$)	RR (95% CI)
Skull	1/31 (3%)	0	
Extremity	3/31 (10%)	1/6 (17%)	
Other	0	1/6 (17%)	
Status of NBPP at 1 y			
Resolved NBPP	6/22 (27%)	0	**1.38 (1.1–1.8)**
Persistent NBPP	16/22 (73%)	6/6 (100%)	
Status of NBPP at 2 y			
Resolved NBPP	7/19 (37%)	0	**1.58 (1.1–2.2)**
Persistent NBPP	12/19 (63%)	4/4 (100%)	
Narakas score III–IV[a]	10/35 (29%)	5/8 (63%)	**2.19 (1.03–4.6)**

Abbreviations: CI, confidence interval; NBPP, neonatal brachial plexus palsy; RR, relative risk.
Data presented as *n* (%).
[a]Narakas III–IV: all five nerves injured.
Bolded if significantly different.

Conflict of Interest
The authors report no conflict of interest.
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