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Original Article

Vacuum Extraction in Preterm Deliveries and Long-Term Neurological Outcome of the Offspring

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ABSTRACT

Background: Concern exists regarding a possible harmful impact of vacuum extraction on the preterm newborn. We aimed to evaluate the long-term pediatric neurodevelopmental outcomes of the preterm offspring after vacuum extraction.

Methods: A population-based cohort analysis was performed comparing the risk for long-term neurological morbidity (up to age 18 years) in preterm (less than 37 completed weeks of gestation) children born via following three delivery modes: vacuum extraction, spontaneous delivery, and Caesarean delivery performed during the second stage of labor. A Kaplan-Meier survival curve was used to compare the cumulative neurological morbidity in all groups. A Cox proportional hazards model was used to control for confounders.

Results: During the study period 11,662 preterm newborns met the inclusion criteria, 97.2% (n = 11,338) of which were born via spontaneous vaginal delivery, 2.3% (n = 267) underwent vacuum extraction, and 0.5% (n = 57) were delivered by Caesarean section during the second stage of labor. Gestational age at delivery median (range) was 36 (29 to 36) weeks for vacuum extractions, 36 (23 to 36) for spontaneous vaginal delivery, and 35 (29 to 36) for Caesarean delivery within second stage of labor. Total pediatric hospitalizations involving neurological diagnoses were comparable between the groups as were the cumulative incidences of total neurological morbidity in the survival curves (log rank $P = 0.723$). In the Cox regression model, vacuum delivery in preterm newborns was not found to be associated with later pediatric neurological hospitalizations.

Conclusions: Vacuum extraction performed on preterm newborns does not appear to be independently associated with severe long-term neurological morbidity, as reflected by later pediatric hospitalizations.

Introduction

More than 150 years ago, the British obstetrician Sir James Young Simpson successfully used a suction cup to assist delivery.[1] A hundred years later, this idea was revived by a Swedish obstetrician, Tage Malmström, who introduced a hollow disc-shaped stainless steel metal cup for vacuum-assisted delivery.[2] Ever since, instrumental delivery is commonly used and its incidence varies from 1% to 23% of deliveries according to different reports.[3] Instrumental deliveries include both vacuum extraction and forceps deliveries, although the number of vacuum-assisted deliveries is consistently rising whereas forceps delivery rates are gradually declining. In the United States, by the year 2000, approximately two thirds of operative vaginal deliveries were by vacuum extraction.[4]

Vacuum extraction is aimed at shortening the second stage of labor, for a number of maternal or fetal indications. Examples of indications include nonreassuring fetal heart rate (NRFHR) patterns or prolonged second stage of labor.[5] Maternal exhaustion or

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disorders that can be exacerbated by stress or exaggerated effort (cardiovascular and neurological disorders) may also indicate instrumental delivery.[6] Instrumental vaginal delivery can safely be used instead of Caesarean delivery (CD) in certain circumstances,[7] thus reducing the number of CDs and the associated short- and long-term complications.

Prematurity is considered a relative contraindication for vacuum extraction. According to the American College of Obstetricians and Gynecologists and the Royal College of Obstetricians and Gynecologists guidelines, vacuum devices should not be used to assist delivery before 34 weeks of gestation because of the potential risk of fetal intraventricular hemorrhage.[8,9] In cases of late preterm delivery (34 0/7 to 36 6/7 weeks of gestation), "safety is uncertain and vacuum procedure should be used with caution."[8,9] Undoubtedly, rates of neonatal complications are higher after operative deliveries in comparison to spontaneous deliveries.[4,6] Although causality could not be established, increased risk of intracranial hemorrhages and brachial plexus injuries have been reported in vacuum deliveries, particularly in short statured women or in the presence of large fetuses.[10,11] Other reported neonatal complications, most of which are reversible, include cephalohematoma (0.1%), facial nerve injury (0.0005%), and retinal hemorrhage (0.002%).[12,13]

The primary etiology of neonatal injuries is not fully established. It is possible that neonatal complications result from the indication for vacuum extraction rather than from the procedure itself. Ghidini et al.[14] found that neonatal head injury after vacuum application was not independently associated with the procedure duration, number of pulls, or cup dislodgements. Importantly, similar or lower rates of serious neonatal complications were shown in operative vaginal delivery when compared with CD performed during the second stage of labor,[15,16] which is the ultimate clinical alternative.

Morales et al.[17] reported no significant differences in neonatal morbidity after vacuum delivery in preterm infants weighing between 1500 and 2499 g compared with those delivered spontaneously. Yet concerns using vacuum in preterm deliveries exist, not only with regards to the immediate outcome but also when considering long-term effects on the offspring. Data in this regard are lacking. We were interested in studying the long-term neurological outcome of preterm offsprings (less than 37 0/7 weeks of gestation) delivered via vacuum extraction compared with those delivered spontaneously or via an emergency CD performed during the second stage of labor.

Materials and Methods

In this population-based retrospective cohort analysis we included only children born before 37 completed weeks of gestation. All deliveries took place at a single tertiary regional university medical center (Soroka University Medical Center, SUMC). SUMC is the second largest hospital in Israel and the only hospital in the Negev (which extends over Israel's southern region). The Negev accounts for over half of Israel's land area, and SUMC serves its entire population of more than one million residents. The Negev population comprises an ethnic minority of Bedouin-Arab along with Jewish residents. Vacuum deliveries are performed at the SUMC at a rate of approximately 6% and CDs in 17% of the deliveries. The institutional review board (SUMC IRB Committee) approved this study in accordance with the Helsinki Declaration ethical standards. Long-term neurological outcome was compared between offsprings born spontaneously, those born via vacuum extractions, and those born via CDs performed during the second stage of labor. All other Caesareans performed for other indications were excluded. Forceps deliveries are not performed in our Institution and thus not included in the analyses. All deliveries occurred during the period between 1991 and 2014. The study is based on non-selective population data.

Outcomes assessed included demographic characteristics, pregnancy and delivery data, and adverse perinatal outcome. The long-term outcomes assessed included all hospitalizations of the offspring up to age 18 years involving at least one diagnosis out of a predefined list from the International Classification of Diseases, ninth revision (ICD-9) codes of all neurological diagnoses, detailed in Supplementary Table 1. Follow-up time was defined as time to an event (neurological-related hospitalization, see included in the ICD-9 code list), or until censored. Censoring occurred in case of death (during hospitalization, other than neurological related) or at age of 18 (which was calculated for each child based on date of birth). Only the first hospitalization for each child was included in the analyses. We have also censored at the end of data availability for each child.

Multiple pregnancies, term deliveries (occurring at 37 completed weeks of gestation or later), and fetuses with congenital malformations were excluded from all analyses.

Data were collected from two databases, which were cross-linked and merged: the computerized hospitalization database ("Demog-ICD9"), and the computerized perinatal database of the Obstetrics and Gynecology Department. The perinatal database consists of information recorded immediately after delivery by an obstetrician. All data concerning demographic characteristics, pregnancy and delivery, perinatal outcome, and hospitalization details are carefully entered into the computerized database. Experienced medical secretaries routinely review the information before entering it into the database to ensure its maximal completeness and accuracy. Coding is performed after assessing medical prenatal care records and routine hospital documents. The Demog-ICD9 database includes demographic information and ICD-9 codes for all medical diagnoses made during hospitalizations at our Institution.

Statistical analysis was performed using the SPSS package 23 ed. (SPSS, Chicago, IL, USA). Categorical data are shown in counts and percentages, and the differences were assessed by χ^2 test for general association. The Student t test and Mann-Whitney U test were used for differences in continuous variables. Kaplan-Meier survival curves were used to compare cumulative neurological hospitalization incidences over time. The differences between the morbidity curves (vacuum extraction, spontaneous vaginal delivery, and second stage CD) were assessed using the log-rank test.

A Cox proportional hazards model analysis was used to establish an independent association between mode of delivery and future cumulative neurological hospitalization incidence while controlling for potential confounders, including gestational age, birth weight, and maternal age. Two dummy variables were created to compare the independent risk of vacuum extraction and second stage CD to spontaneously vaginal delivery. All analyses were two-sided, and a P value of <0.05 was considered statistically significant.

Results

During the study 11,662 preterm newborns met the inclusion criteria, of which 97.2% (n = 11,338) were born via spontaneous vaginal delivery, 2.3% (n = 267) underwent vacuum extraction, and 0.5% (n = 57) were delivered by second stage CD. Table 1 depicts the maternal demographic and pregnancy characteristics of the three study groups. In the vacuum extraction group, there was a significantly higher percentage of primigravidas in comparison to the spontaneous delivery and CD groups (70.8% versus 30.2% and 54.4%, respectively, $P < 0.001$). Maternal diabetes and hypertension were more prevalent in the CD group when compared with the vacuum

TABLE 1.
Maternal Demographics and Pregnancy Characteristics According to Mode of Delivery in Children Born via Spontaneous Vaginal Delivery Compared With Vacuum Extraction and Second Stage Caesarean Delivery Before 37 0/7 Weeks of Gestation

Characteristics	Vacuum Extraction n = 267	Spontaneous Vaginal Delivery n = 11,338	Caesarean Delivery (Second Stage) n = 57	*P* Value
Maternal age mean (years)	26.4 (±5.934)	27.1 (±6.054)	28.6 (±6.795)	0.029
Parity				<0.001
1: n = 3639	189 (70.8)	3419 (30.2)	31(54.4)	
2-4: n = 5565	60 (22.6)	5493 (48.5)	12 (0.2)	
5+: n = 2456	18 (6.7)	2424 (21.4)	14 (0.6)	
Diabetes mellitus				0.002
(Pregestational and gestational) n = 630	16 (6)	605 (5.3)	9 (15.8)	
Hypertension (chronic and gestational) n = 982	29 (10.9)	939 (8.3)	14 (24.6)	<0.001

Data are presented as the mean ± S.D., number (%). Significance for differences was measured using χ^2 and Mann-Whitney tests or Student *t* test.

and spontaneous delivery groups (15.8% versus 6% and 5.3%, respectively, $P = 0.002$ for diabetes, and 24.6% versus 10.9% and 8.3%, respectively, $P < 0.001$ for hypertension).

Delivery and immediate perinatal outcomes are presented in Table 2. Distribution of the different gestational ages in the three groups was as follows: mean gestational age for the vacuum group was 35.2 (±2.2) weeks, 34.4 (±3.3) weeks for the spontaneous delivery group, and 33.6 (±6.1) weeks for the CD group—of gestation ($P < 0.001$). In addition, gestational age at delivery range was 36 (29 to 36) weeks for vacuum extractions, 36 (23 to 36) weeks for spontaneous vaginal delivery, and 35 (29 to 36) weeks for CD within second stage of labor.

NRFHR was significantly more common in the vacuum group (70% versus 0.3% in the spontaneous delivery group and 26.3% in the CD group, $P < 0.001$), whereas low Apgar scores (less than 7) at one minute were less common in the spontaneous delivery group in comparison to vacuum delivery and CD (5.5% versus 10.5% and 36.8%, respectively, $P < 0.001$). Low (less than 7) 5-minute Apgar scores were noted less commonly in the vacuum group (0.4% versus 3.2% in the CD group and 8.8% in the spontaneous vaginal delivery group, $P = 0.002$).

Perinatal mortality was present only in the spontaneous delivery group with intrauterine fetal death rate of 3.5%, and lower rates for intrapartum and postpartum deaths.

Length of follow-up, calculated according to the mean ± S.D. as well as median and range, was not significantly different among the study groups (Table 2).

Long-term neurological morbidity of the offspring, according to delivery mode, is presented in Table 3. Comparable rates of hospitalizations involving neurological morbidity up to age 18 years were noted in the three groups. In addition, the Kaplan-Meier survival curve demonstrated similar patterns of the long-term neurological hospitalizations' cumulative incidences in the three modes of delivery (Fig, log rank *P* value of 0.723).

Table 4 presents the Cox hazards regression models for the association between long-term neurological morbidity in the offspring (up to age 18 years) and mode of delivery. Several important confounders including maternal age, gestational age,

TABLE 2.
Delivery and Immediate Perinatal Outcome According to Mode of Delivery in Children Born via Spontaneous Vaginal Delivery Compared With Vacuum Extraction and Second Stage Caesarean Delivery Before 37 0/7 Weeks of Gestation

Characteristics	Vacuum Extraction n = 267	Spontaneous Vaginal Delivery n = 11,338	Caesarean Delivery (Second Stage) n = 57	*P* Value
Gestational age at birth				
Mean ± S.D. (weeks)	35.2 (±2.2)	34.4 (±3.34)	33.6 (±6.08)	
Median, range (weeks)	36 (29-36)	36 (23-36)	35 (29-36)	<0.001
Gestational age <34 weeks of gestation n = 1984	18 (6.7)	1956 (17.3)	10 (17.5)	<0.001
Gender (female) n = 5008	133 (49.8)	5360 (47.3)	22 (38.6)	0.300
Gender (male) n = 5787	134 (50.2)	5618 (52.7)	35 (61.4)	
Low birth weight (<2500 g) n = 5559	109 (40.8)	5428 (47.9)	22 (38.6)	0.029
Very low birth weight (<1500 g) n = 796	4 (1.5)	791 (7)	1 (1.8)	<0.001
NRFHR n = 238	187 (70)	36 (0.3)	15 (26.3)	<0.001
Apgar score at 1 minute				n/a
Mean (points)	8.42 (±1.3)	8.80 (±0.08)	7.13 (±2.3)	
Median (points)	9 (3-10)	9 (0-10)	8 (2-10)	
Apgar score at 5 minutes				n/a
Mean ± S.D. (points)	9.78 (±0.05)	9.89 (±0.05)	9.40 (±1.2)	
Median, range (points)	10 (7-10)	10 (1-10)	10 (4-10)	
Low Apgar score at 1 minute (<7) n = 633	28 (10.5)	584 (5.5)	21 (36.8)	<0.001
Low Apgar score at 5 minutes (<7) n = 347	1 (0.4)	341 (3.2)	5 (8.8)	0.002
IUFD n = 400	0	400 (3.5)	0	0.003
IPD n = 25	0	25 (0.2)	0	0.699
PPD n = 287	0	287 (2.5)	0	0.015
Mean birth weight (g)	2600 ± 478.0	2548 ± 513.9	2679 ± 597.6	0.086
Follow-up time length				0.062
Mean ± S.D. (years)	9.79 (±5.8)	10.47 (±5.9)	9.27 (±6.0)	
Median, range (years)	9.47 (0.05-18.01)	11.04 (0-18.01)	9.11 (0.08-18.01)	

Abbreviations:
IPD = intrapartum death
IUFD = intrauterine fetal death
NRFHR = Nonreassuring fetal heart rate
PPD = postpartum death
Data are presented as the mean ± S.D., median (min; max), number (%). Significance for differences was measured using χ^2 and Mann-Whitney tests or Student *t* test.

TABLE 3.
Comparison of the Long-Term Neurological Morbidity in Children (up to Age 18 Years) Born via Spontaneous Preterm Vaginal Delivery Compared With Those Born Using Vacuum Extraction and Second Stage CD Performed Before 37 0/7 Weeks of Gestation

Pediatric Neurological Morbidity	Vacuum Extraction n = 267 (%)	Spontaneous Vaginal Delivery n = 11,338 (%)	Caesarean Delivery (Second Stage) n = 57 (%)	*P* Value
Eating disorders (n = 29)	1 (0.4)	28 (0.3)	0 (0)	0.872
Sleeping disorders (n = 2)	0 (0)	2 (<0.001)	0 (0)	0.970
Movement disorders (n = 255)	4 (1.5)	160 (1.5)	0 (0)	0.647
Epilepsy	1 (0.4)	89 (0.8)	1 (1.8)	0.530
Cerebral palsy (n = 21)	0 (0)	21 (0.2)	0 (0)	0.726
Psychiatric disorders (n = 72)	4 (1.5)	68 (0.6)	0 (0)	0.089
Autism (n = 1)	0 (0)	1 (<0.001)	0 (0)	0.985
ADHD (n = 12)	0 (0)	12 (0.1)	0 (0)	0.833
Developmental disorders (n = 16)	1 (0.4)	15 (0.1)	0 (0)	0.590
Degenerative disorders (n = 15)	1 (0.4)	14 (0.1)	0 (0)	0.549
Other (n = 59)	1 (0.4)	58 (0.5)	0 (0)	0.797
TOTAL neurological hospitalizations (n = 457)	11 (4.1)	445 (4.5)	1 (1.8)	0.657

Abbreviations:
ADHD = Attention deficit and hyperactive disorder
CD = Caesarean delivery
Data are presented as number (%).

birth weight less than 1500 g, maternal diabetes, and hypertension were analyzed and neither vacuum extraction nor second stage CD were independently associated with an increased risk for later neurological hospitalizations of the offspring compared with spontaneous vaginal delivery (vacuum versus spontaneous vaginal delivery, adjusted hazard ratio 0.4, 95% confidence interval 0.05 to 3.1, $P = 0.371$; vacuum versus spontaneous vaginal delivery, adjusted hazard ratio 0.9, 95% confidence interval 0.5 to 1.7, $P = 0.833$).

Only five failed vacuum extractions leading to an emergency CD were noted in the cohort, details of which are presented in Table 5. No perinatal mortality cases or any later neurological diagnoses were identified in this small group of offsprings.

Discussion

In this large cohort of preterm deliveries, we found no difference in the long-term pediatric neurological morbidity rates of offspring born by vacuum extraction compared with spontaneous delivery or CD during the second stage of labor.

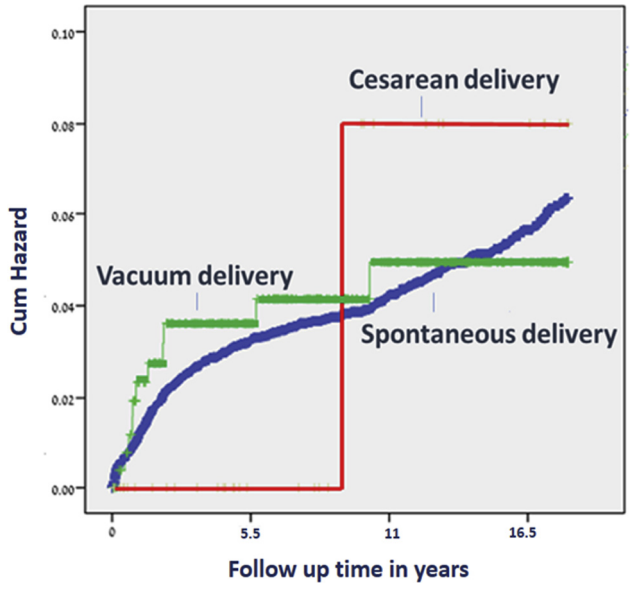

FIGURE. Kaplan-Meier survival curve demonstrating the cumulative incidence of neurological hospitalizations in offspring born before 37 weeks of gestation via spontaneous vaginal delivery compared with those born using vacuum extraction and Caesarean delivery performed during the second stage of labor (log rank $P = 0.723$) (see Results section). The color version of this figure is available in the online edition.

As with all manual procedures, vacuum extraction is highly operator dependent, and results are indication dependent as well. As obstetricians, we are all concerned with the potential adverse outcomes, both in the short term and more so in the long term, related to operative deliveries. Although it is well established that vacuum deliveries are associated with increased rates of short-term neonatal morbidity,[14,18,19] long-term outcomes of term newborns delivered via vacuum extraction are comparable to that of newborns delivered spontaneously.[20]

One of the main concerns regarding the safety of vacuum-assisted delivery is the risk of cranial trauma, including subgaleal hemorrhage, intracranial hemorrhage, and subdural hemorrhage, because of tentorial tears. In addition to the potential damage during the vacuum itself, preterm delivery is, on its own, a risk factor associated with subgaleal hematomas and periventricular-intraventricular hemorrhage.[13,21,22] Thus these concerns are magnified.

Management of prolonged second stage of labor is a common clinical dilemma. On one hand, NRFHR monitoring during the second stage of labor increases the risk of neonatal intensive care unit admission, birth asphyxia, birth trauma, low 5-minute Apgar score, and perinatal mortality.[23-25] On the other hand, if the clinician chooses to intervene, for example performing an instrumental delivery, other concerns arise, in terms of both immediate and long-term adverse outcomes. These concerns are all magnified in the case of preterm delivery. Some predisposing factors for complications after assisted delivery were previously suggested. Fetal macrosomia was found to be a significant risk factor for intracranial hemorrhage, neonatal convulsions, and brachial plexus injuries during vacuum procedures.[26,27] However, macrosomia is rarely a concern in preterm deliveries.

Another important point is the fact that intracranial hemorrhage was found in higher rates among infants delivered after labor dystocia and prolonged second stage, regardless of delivery mode (vacuum extraction, forceps, or CD) suggesting that the common risk factor for intracranial hemorrhage is the abnormal labor process rather than the mode of delivery.[28]

Of interest, Thorngren-Jerneck and Herbst[29] suggested that both a successful instrumental delivery and an emergency Caesarean delivery are associated with increased cerebral palsy risk in term infants. Focusing on preterm deliveries and immediate outcome of preterm newborns, small series of vacuum-assisted deliveries in preterm fetuses report no significant differences regarding the risk

TABLE 4.
Cox Hazards Model of Long-Term Pediatric Neurological Morbidity Associated With Mode of Delivery Before 37 0/7 Weeks of Gestation

Offspring Long-Term Neurological Morbidity	Adjusted HR	95% CI of HR	*P* Value
Vacuum extraction (versus spontaneous vaginal delivery)	0.9	0.5-1.7	0.833
Second stage Caesarean delivery (versus spontaneous vaginal delivery)	0.4	0.05-3.1	0.371
Maternal hypertension	1.2	0.9-1.4	0.204
Maternal diabetes	1.09	0.8-1.4	0.511
Maternal age	0.99	0.9-1.0	0.824
Birth weight <1500 g	1.7	1.3-2.3	<0.001
Gestational age	0.97	0.95-1	0.002

Abbreviations:
CI = Confidence interval
HR = Hazard ratio

of periventricular-intraventricular hemorrhage compared with spontaneous preterm deliveries.[30]

All these data suggest that it may possibly be gestational age, prematurity, fetal weight, and labor course that impact the neurological outcome in the offspring, rather than the delivery mode itself. Our results reinforce this understanding.

The vast majority of vacuum-assisted deliveries in our cohort were performed on primiparous women (189 cases, 70.8%). The most common indication for vacuum extraction in our cohort was NRFHR tracings (187 cases, 70%). Accordingly, a low (less than 7) one-minute Apgar score was more common in the vacuum group compared with the spontaneous delivery (10.5% versus 5.5%, respectively, *P* value<0.001). Interestingly, a low five-minute Apgar score was significantly more common in newborns delivered spontaneously and by CD compared with those delivered via vacuum extraction (3.2%, 8.8%, and 0.4% respectively, *P* value = 0.002). The explanation may lie in the fact that in cases when fetal distress is suspected and treated promptly by vacuum extraction the immediate outcomes are more favorable.

Reportedly (and intuitively), suboptimal care can influence the immediate and late obstetrical outcomes. This finding is supported by Yamada et al.[31] who found that suboptimal intrapartum care (defined as delayed reaction because of misinterpretation of fetal heart rate tracing, or inappropriate trial of instrumental delivery) is the greatest risk factor for neonatal encephalopathy leading to cerebral palsy among mature and healthy fetuses. Thus avoidance of vacuum delivery when indicated may also carry adverse neurological consequences.

Although CD rates have increased worldwide, operative vaginal delivery rates continue to decline.[32-34] In private facilities, CD rates are even higher.[35] The reason for this trend is probably not purely medical. In the United States, CD rates have increased from 26% to 36.5% between the years 2003 and 2009, being confirmed by reports published more recently[36,37]; 50.0% of the increase was attributable to an increase in primary CDs. Among the documented indications, nonreassuring fetal status, arrest of dilation, multiple gestations, preeclampsia, suspected macrosomia, and maternal request increased over time, whereas other obstetrical indications did not.[33] Other explanations for the ever-rising CD rates are medicolegal issues, assisted reproductive technique use with higher multiple pregnancy rates, advanced maternal age, and frequent patient request.[33] Caesareans performed during the second stage of labor carry high maternal morbidity rates.[38] Moreover, operative vaginal delivery is associated with similar or even lower rates of serious neonatal complications compared with CD performed during the second stage of labor.[15,16] Apparently, fetal status during the second stage of labor, and not the mode of delivery, predicts fetal outcome.[28,29]

TABLE 5.
Characteristics of the Failed Vacuum Group

Failed Vacuum Group Parameters	n = 5
Neurological hospitalizations	0
Peripartum mortality (IUFD, IPD, PPD)	0
Gender (Female)	3
Low birth weight (<2500 g)	5
Very low birth weight (<1500 g)	0
NRFHR	5
Low Apgar score at 1 minute (<7)	5
Low Apgar score at 5 minutes (<7)	1

Abbreviations:
IPD = Intrapartum death
IUFD = Intrauterine fetal death
NRFHR = Nonreassuring fetal heart rate
PPD = Postpartum death

The main strength of our study is in the population-based nature of its data, and the fact that our hospital is the only medical center serving the entire population of an extremely large area. The hospital provides both maternity and pediatric services and thus as long as patients live in the area, they would probably be diagnosed and treated in this hospital. Our institution provides the largest delivery service in the country, with over 1200 births per month. Because it is the only tertiary hospital in the region, most patients receive their entire treatment in our facility. The population-based nature of the cohort, without a selection bias, enhances the robustness of our conclusions. Broad inclusion criteria and limited exclusion criteria in our study produce a study population that is more representative of the target population. Nonetheless, several limitations should be addressed when considering our results. The major limitation resides in the retrospective nature of the data that are based on a database registry, which has intrinsic limitations related to the type of retrieved information as well as the possibility of misclassification of the outcome (neurological morbidity) exists. It is also probable that some patients with mild neurological defects are undiagnosed or are treated in an outpatient setting and therefore classified as "healthy." This bias may deviate our results toward the null hypothesis. Only severe examples of neurological morbidity, leading to hospitalizations, were identified and classified as such. Thus our conclusions must be restricted to such cases. Although our region is characterized by positive immigration in general, immigration of offspring born outside the hospital coverage area is possible. Another important point is the fact that we were able to follow offspring up to age 18 years. It is possible that different morbidities might become apparent only at an older age. This important point remains to be investigated in future studies. In addition, for those infants who were born as recently as 2014, only three to four years of follow-up is available. As a consequence, some neurological morbidity may have been missed.

Also, according to the institutional protocols and national guidelines there is an upper limit of three attempts before declaring a failed vacuum delivery leading to a Caesarean section. Unfortunately, we have no data in our database related to the number of attempts (one, two, or three) performed, thus we cannot correlate outcomes to this variable. Finally, even in a large and busy delivery room such as the one at our institution, for a follow-up period of

more than 20 years, the number of vacuum deliveries performed in preterm deliveries is small (n = 267). Thus the power of our findings is limited. Nevertheless, this is the first study to investigate the long-term neurological outcome of preterm offspring delivered via vacuum extraction, and the results are reassuring.

Conclusions

There is no increased risk of adverse neurological outcome in the exposed group, up to age 18 years compared with other delivery modes. Vacuum-assisted delivery appears to be a safe and legitimate option for late preterm deliveries necessitating intervention during the second stage of labor, although further studies are needed to substantiate our results.

Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.pediatrneurol.2018.12.010.

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