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EFFECT OF MODE OF DELIVERY IN NULLIPAROUS WOMEN ON NEONATAL INTRACRANIAL INJURY

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ABSTRACT

Background Infants delivered by vacuum extraction or other operative techniques may be more likely to sustain major injuries than those delivered spontaneously, but the extent of the risk is unknown.

Methods From a California data base, we identified 583,340 live-born singleton infants born to nulliparous women between 1992 and 1994 and weighing between 2500 and 4000 g. One third of the infants were delivered by operative techniques. We evaluated the relation between the mode of delivery and morbidity in the infants.

Results Intracranial hemorrhage occurred in 1 of 860 infants delivered by vacuum extraction, 1 of 664 delivered with the use of forceps, 1 of 907 delivered by cesarean section during labor, 1 of 2750 delivered by cesarean section with no labor, and 1 of 1900 delivered spontaneously. As compared with the infants delivered spontaneously, those delivered by vacuum extraction had a significantly higher rate of subdural or cerebral hemorrhage (odds ratio, 2.7; 95 percent confidence interval, 1.9 to 3.9), as did the infants delivered with the use of forceps (odds ratio, 3.4; 95 percent confidence interval, 1.9 to 5.9) or cesarean section during labor (odds ratio, 2.5; 95 percent confidence interval, 1.8 to 3.4), but the rate of subdural or cerebral hemorrhage associated with vacuum extraction did not differ significantly from that associated with forceps use (odds ratio for the comparison with vacuum extraction, 1.2; 95 percent confidence interval, 0.7 to 2.2) or cesarean section during labor (odds ratio, 0.9; 95 percent confidence interval, 0.6 to 1.4).

Conclusions The rate of intracranial hemorrhage is higher among infants delivered by vacuum extraction, forceps, or cesarean section during labor than among infants delivered spontaneously, but the rate among infants delivered by cesarean section before labor is not higher, suggesting that the common risk factor for hemorrhage is abnormal labor. (N Engl J Med 1999; 341:1709-14.)

FIVE to 25 percent of nulliparous pregnant women have operative vaginal delivery.[1] Although forceps have been used in obstetrics since the early 19th century, vacuum extraction was not widely used until the 1950s. The popularity of vacuum extraction has steadily increased with the development of newer vacuum cups; from 1985 to 1992, there was a 37 percent increase in the use of vacuum extraction and a 22 percent decline in the use of forceps in the United States.[2]

The risk of serious neonatal injury associated with vacuum extraction has been controversial. Multiple studies have demonstrated the safety of soft vacuum extractors as compared with either metal vacuum extractors or forceps. Despite the alleged safety of vacuum extraction, it can result in major fetal trauma ranging from brachial plexus injury as a result of shoulder dystocia[3] to scalp injuries[4,5] and intracranial hemorrhage, including tentorial tears with hemorrhage and skull fractures with hemorrhage.[6-12] In particular, subgaleal hemorrhage has been strongly associated with vacuum extraction.[13-16] The Food and Drug Administration recently released a Public Health Advisory, citing a quintupling of the rate of serious neonatal events associated with vacuum extraction in the past 4 years, as compared with the previous 11 years.[17] We studied a large number of nulliparous women in order to determine the incidence of rare neonatal disorders and their association with various modes of delivery, particularly vacuum extraction.

METHODS

We used a data base from the Health Information for Policy Project that links birth and death certificates in California with

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TABLE 1. SINGLETON INFANTS BORN TO NULLIPAROUS WOMEN IN CALIFORNIA BETWEEN 1992 AND 1994, ACCORDING TO THE MODE OF DELIVERY.*

YEAR	SPONTANEOUS DELIVERY	VACUUM EXTRACTION	CESAREAN SECTION	FORCEPS DELIVERY	VACUUM EXTRACTION AND FORCEPS DELIVERY	TOTAL
	number of infants (percent)					
1992	133,486 (66.3)	18,667 (9.3)	41,502 (20.6)	6,519 (3.2)	1105 (0.5)	201,279
1993	128,737 (66.6)	19,499 (10.1)	39,235 (20.3)	4,948 (2.6)	920 (0.5)	193,339
1994	125,576 (66.5)	21,188 (11.2)	36,688 (19.4)	4,478 (2.4)	792 (0.4)	188,722
Total	387,799 (66.5)	59,354 (10.2)	117,425 (20.1)	15,945 (2.7)	2817 (0.5)	583,340

*Data are restricted to live-born infants weighing 2500 to 4000 g.

maternal and neonatal hospital-discharge records for the 328 civilian hospitals that report to the Office of State Health Planning and Development. The data base includes 98 percent of all births in the state. The clinical information in the data base is limited to data entered on birth certificates, death certificates, and *International Classification of Diseases, 9th Revision* (ICD-9) diagnostic codes and *Current Procedural Terminology* (CPT) procedural codes abstracted from the mother's and infant's discharge summaries. The study was approved by the institutional review board of the Office of State Health Planning and Development.

We studied all live-born singleton neonates born to nulliparous women between January 1, 1992, and December 31, 1994, and weighing between 2500 and 4000 g. Only nulliparous women were studied because they have an increased incidence of operative delivery. Vaginal breech deliveries were excluded. Neonates were grouped according to the mode of delivery: 387,799 infants were delivered spontaneously, 59,354 by vacuum extraction, 117,425 by cesarean delivery, 15,945 with use of forceps, and 2817 by combined use of forceps and vacuum extraction. The type of vacuum cup or forceps could not be determined because of the nature of the data base. Of the women who had cesarean deliveries, 84,417 were in labor at the time of delivery and 33,008 were not, according to the ICD-9 or CPT code. In 2342 of the women who were in labor when the cesarean delivery was performed, an attempt at operative vaginal delivery had been unsuccessful; in 82,075 women, cesarean delivery was performed during labor without an attempt at operative vaginal delivery.

ICD-9 and CPT codes for conditions reflecting major neonatal morbidity were determined from the discharge records for the infants. Codes for subdural or cerebral hemorrhage, intraventricular hemorrhage, subarachnoid hemorrhage, facial-nerve injury, and brachial plexus injury were considered to be direct indicators of major injury. Codes for convulsions, central nervous system depression, difficulty with feeding, and mechanical ventilation were considered to be indirect indicators of injury. Data on deaths of infants before discharge were included in the analysis.

The data were analyzed with the chi-square test or Fisher's exact test, and odds ratios with 95 percent confidence intervals were calculated. All statistical tests were two-sided.

RESULTS

There were 583,340 deliveries that met the study criteria. The distribution of infants according to the type of delivery is shown in Table 1. For all three years of the study, about one third of the women had operative deliveries.

Death before discharge occurred in 0.2 per 1000 infants delivered spontaneously, 0.3 per 1000 delivered by vacuum extraction, 0.5 per 1000 delivered with the use of forceps, 0.6 per 1000 delivered with the use of vacuum extraction and forceps combined, and 0.8 per 1000 delivered by cesarean section. The death rate did not differ significantly between infants delivered spontaneously and those delivered by vacuum extraction (odds ratio for the comparison with spontaneous delivery, 1.5; 95 percent confidence interval, 0.8 to 2.8), forceps delivery (odds ratio, 1.9; 95 percent confidence interval, 0.6 to 5.4), or vacuum extraction combined with forceps delivery (odds ratio, 2.6; 95 percent confidence interval, 0.4 to 5.4). Significantly more deaths occurred among infants delivered by cesarean section than among those delivered spontaneously (odds ratio, 3.7; 95 percent confidence interval, 2.6 to 5.4). The death rate was the same for infants born by cesarean delivery during labor and for those born by cesarean delivery with no labor (0.8 per 1000).

Vacuum Extraction

As compared with infants born by spontaneous vaginal delivery, those delivered by vacuum extraction had significantly higher rates of subdural or cerebral hemorrhage, brachial plexus injury, convulsions, central nervous system depression, and mechanical ventilation, but the rates of intraventricular hemorrhage, subarachnoid hemorrhage, facial-nerve injury, and feeding difficulty did not differ significantly between the two groups of infants (Table 2). Even though vacuum extraction was significantly associated with major morbidity, the absolute risk of morbidity was low. Intracranial hemorrhage (subdural, cerebral, intraventricular, or subarachnoid) occurred in 1 of every 860 infants delivered by vacuum extraction, as compared with 1 of 1900 delivered spontaneously (odds ratio, 2.2; 95 percent confidence interval, 1.7 to 2.9).

Forceps Delivery

Infants delivered with the use of forceps had significantly higher rates of subdural or cerebral hem-

TABLE 2. INCIDENCE OF MAJOR NEONATAL MORBIDITY AND RISK ASSOCIATED WITH OPERATIVE PROCEDURES AS COMPARED WITH SPONTANEOUS DELIVERY.*

CONDITION	SPONTANEOUS (N=387,799)	VACUUM (N=59,354)		FORCEPS (N=15,945)		VACUUM AND FORCEPS (N=2817)	
	Incidence	*Incidence*	*Odds Ratio*	*Incidence*	*Odds Ratio*	*Incidence*	*Odds Ratio*
Subdural or cerebral hemorrhage	2.9	8.0	2.7 (1.9–3.9)	9.8	3.4 (1.9–5.9)	21.3	7.3 (2.9–17.2)
Intraventricular hemorrhage	1.1	1.5	1.4 (0.7–3.0)	2.6	2.5 (0.9–6.9)	3.7	3.5 (1.5–25.2)
Subarachnoid hemorrhage	1.3	2.2	1.7 (0.9–3.2)	3.3	2.5 (0.9–6.6)	10.7	8.2 (2.1–27.4)
Facial-nerve injury	3.3	4.6	1.7 (0.9–2.1)	45.4	13.6 (10.0–18.4)	28.5	8.5 (3.9–18.0)
Brachial plexus injury	7.7	17.6	2.3 (1.8–2.9)	25.0	3.2 (2.3–4.6)	46.4	6.0 (3.3–10.7)
Convulsions	6.4	11.7	1.8 (1.4–2.4)	9.8	1.6 (0.9–2.7)	24.9	3.9 (1.7–8.6)
CNS depression	3.1	9.2	2.9 (2.1–4.1)	5.2	1.4 (0.6–2.8)	21.3	6.9 (2.7–16.2)
Feeding difficulty	68.5	72.1	1.1 (1.0–1.2)	74.6	1.1 (0.9–1.3)	60.7	0.9 (0.5–1.5)
Mechanical ventilation	25.8	39.1	1.5 (1.3–1.8)	45.4	1.8 (1.4–2.3)	50.0	1.9 (1.1–3.4)

	CESAREAN									
	TOTAL (N=117,425)		DURING LABOR (N=84,417)		DURING LABOR, FAILED VAGINAL DELIVERY (N=2342)†		DURING LABOR, NO ATTEMPT AT VAGINAL DELIVERY (N=82,075)†		NO LABOR (N=33,008)	
	Incidence	*Odds Ratio*	*Incidence*	*Odds Ratio*	*Incidence*	*Odds Ratio*	*Incidence*	*Odds Ratio*	*Incidence*	*Odds Ratio*
Subdural or cerebral hemorrhage	6.7	2.3 (1.7–3.1)	7.4	2.5 (1.8–3.4)	25.7	8.8 (3.9–19.9)	6.8	2.3 (1.7–3.2)	4.1	1.4 (0.8–2.6)
Intraventricular hemorrhage	2.1	2.0 (1.2–3.3)	2.5	2.3 (1.4–4.0)	0.0	0.0 (0.0–1.1)	2.6	2.4 (1.4–4.1)	0.8	0.6 (0.1–2.5)
Subarachnoid hemorrhage	0.9	0.7 (0.4–1.4)	1.2	0.9 (0.4–1.9)	4.3	3.3 (0.5–23.9)	1.1	0.9 (0.4–1.7)	0.0	0.0 (0.0–19.7)
Facial-nerve injury	3.5	1.1 (0.7–1.5)	3.1	0.9 (0.6–1.4)	12.8	3.8 (1.2–12.1)	2.8	0.8 (0.5–1.3)	4.9	1.5 (0.8–2.6)
Brachial plexus injury	3.0	0.4 (0.3–0.5)	1.8	0.2 (0.1–0.4)	8.6	1.1 (0.3–4.4)	1.6	0.2 (0.1–0.4)	4.1	0.5 (0.3–1.0)
Convulsions	18.7	2.9 (2.4–3.6)	21.3	3.3 (2.8–4.1)	68.8	10.8 (6.5–17.8)	19.9	3.1 (2.6–3.8)	8.6	1.4 (0.9–2.1)
CNS depression	8.9	2.9 (2.2–3.7)	9.6	3.1 (2.3–4.1)	17.1	5.5 (1.7–15.5)	9.4	3.0 (2.3–4.0)	6.7	2.2 (1.3–3.6)
Feeding difficulty	114.7	1.7 (1.6–1.8)	117.2	1.7 (1.6–1.8)	94.8	1.4 (0.9–2.1)	117.9	1.7 (1.6–1.8)	106.3	1.6 (1.4–1.8)
Mechanical ventilation	96.0	3.7 (3.4–4.1)	103.2	4.0 (3.6–4.3)	156.1	6.0 (4.3–8.3)	101.7	2.6 (2.2–3.0)	71.3	2.8 (2.4–3.3)

*The incidence is expressed as the number of cases per 10,000 infants. Numbers in parentheses are 95 percent confidence intervals. CNS denotes central nervous system.

†Vaginal delivery refers to delivery with the use of vacuum extraction, forceps, or both.

orrhage, facial-nerve injury, brachial plexus injury, and mechanical ventilation than did infants delivered spontaneously (Table 2). As compared with vacuum extraction, forceps delivery was significantly associated only with facial-nerve injury (Table 3). Intracranial hemorrhage was significantly more frequent in infants delivered with the use of forceps (1 of every 664) than in those delivered spontaneously (odds ratio, 2.9; 95 percent confidence interval, 1.8 to 4.4), but the incidence in infants delivered with the use of forceps did not differ significantly from that in infants delivered by vacuum extraction (odds ratio, 1.3; 95 percent confidence interval, 0.8 to 2.1).

Vacuum Extraction and Forceps Delivery

As compared with spontaneous delivery, vacuum extraction combined with forceps delivery was associated with significantly higher rates of subdural or cerebral hemorrhage, intraventricular hemorrhage, subarachnoid hemorrhage, facial-nerve injury, brachial plexus injury, convulsions, central nervous system depression, and mechanical ventilation (Table 2). The combination of vacuum extraction and forceps delivery was associated with significantly higher rates of subdural or cerebral hemorrhage, subarachnoid hemorrhage, facial-nerve injury, and brachial plexus injury than was vacuum extraction alone (Table 3). Intracranial hemorrhage occurred in 1 of every 256 infants delivered by vacuum extraction with forceps delivery, a rate that was 7.4 times (95 percent confidence interval, 3.9 to 14.0) the rate associated with spontaneous delivery and 3.4 times (95 percent confidence interval, 1.7 to 6.6) that associated with vacuum extraction alone.

Cesarean Delivery

As compared with spontaneous delivery, cesarean delivery was associated with significantly higher rates

TABLE 3. INCIDENCE OF MAJOR NEONATAL MORBIDITY AND RISK ASSOCIATED WITH OTHER OPERATIVE PROCEDURES AS COMPARED WITH VACUUM EXTRACTION.*

CONDITION	VACUUM (N=59,354)	FORCEPS (N=15,945)		VACUUM AND FORCEPS (N=2817)	
	Incidence	*Incidence*	*Odds Ratio*	*Incidence*	*Odds Ratio*
Subdural or cerebral hemorrhage	8.0	9.8	1.2 (0.7–2.2)	21.3	2.7 (1.2–6.3)
Intraventricular hemorrhage	1.5	2.6	1.7 (0.5–5.6)	3.7	2.4 (0.3–19.1)
Subarachnoid hemorrhage	2.2	3.3	1.5 (0.5–4.2)	10.7	4.8 (1.4–20.0)
Facial-nerve injury	4.6	45.4	9.9 (6.3–15.4)	28.5	6.2 (2.8–13.7)
Brachial plexus injury	17.6	24.9	1.4 (1.0–2.1)	46.4	2.6 (1.4–4.8)
Convulsions	11.7	9.8	0.8 (0.5–1.5)	24.9	2.1 (1.0–4.6)
CNS depression	9.2	5.2	0.6 (0.3–1.2)	21.3	2.3 (1.0–5.4)
Feeding difficulty	72.1	74.6	1.0 (0.8–1.3)	60.7	0.8 (0.5–1.4)
Mechanical ventilation	39.1	45.4	1.2 (0.9–1.5)	50.0	1.3 (0.8–2.2)

	CESAREAN							
	DURING LABOR (N=84,417)		DURING LABOR, FAILED VAGINAL DELIVERY (N=2342)†		DURING LABOR, NO ATTEMPT AT VAGINAL DELIVERY (N=82,075)†		NO LABOR (N=33,008)	
	Incidence	*Odds Ratio*	*Incidence*	*Odds Ratio*	*Incidence*	*Odds Ratio*	*Incidence*	*Odds Ratio*
Subdural or cerebral hemorrhage	7.4	0.9 (0.6–1.4)	25.7	3.2 (1.4–7.5)	6.8	0.9 (0.6–1.3)	4.1	0.5 (0.3–1.0)
Intraventricular hemorrhage	2.5	1.6 (0.8–3.6)	0.0	0.0 (0.0–14.9)	2.6	1.7 (0.8–3.6)	0.8	0.3 (0.1–1.3)
Subarachnoid hemorrhage	1.2	0.5 (0.2–1.2)	4.3	1.9 (0.3–14.8)	1.1	0.5 (0.2–1.2)	0.0	0.0 (0.0–0.7)
Facial-nerve injury	3.1	0.7 (0.4–1.2)	12.8	2.8 (0.9–9.2)	2.8	0.6 (0.4–1.1)	4.9	1.1 (0.5–2.1)
Brachial plexus injury	1.8	0.1 (0.1–0.2)	8.6	0.5 (0.1–2.0)	1.6	0.1 (0.1–0.2)	4.1	0.2 (0.1–0.5)
Convulsions	21.3	1.8 (1.4–2.4)	68.8	5.9 (3.4–10.1)	19.9	1.7 (1.3–2.3)	8.6	0.7 (0.5–1.2)
CNS depression	9.6	1.1 (0.7–1.5)	17.1	1.9 (0.7–5.2)	9.4	1.0 (0.7–1.5)	6.7	0.7 (0.4–1.3)
Feeding difficulty	117.2	1.6 (1.4–1.8)	94.8	1.3 (0.9–2.1)	117.9	1.6 (1.5–1.8)	106.3	1.5 (1.3–1.7)
Mechanical ventilation	103.2	2.6 (2.3–3.0)	156.1	4.0 (2.8–5.6)	101.7	2.6 (2.2–3.0)	71.3	1.8 (1.5–2.2)

*The incidence is expressed as the number of cases per 10,000 infants. Numbers in parentheses are 95 percent confidence intervals. CNS denotes central nervous system.

†Vaginal delivery refers to delivery with the use of vacuum extraction, forceps, or both.

of subdural or cerebral hemorrhage, intraventricular hemorrhage, convulsions, central nervous system depression, feeding difficulty, and mechanical ventilation but a lower rate of brachial plexus injury (Table 2). Cesarean delivery performed during labor was associated with significantly higher rates of subdural or cerebral hemorrhage, intraventricular hemorrhage, convulsions, central nervous system depression, feeding difficulty, and mechanical ventilation than was spontaneous delivery (Table 2). As compared with vacuum extraction, cesarean delivery during labor was associated with significantly higher rates of convulsions, feeding difficulty, and mechanical ventilation but not with significantly higher rates of intracranial hemorrhage (Table 3). Intracranial hemorrhage occurred in 1 of every 907 infants born by cesarean delivery during labor, a rate that was 2.1 times (95 percent confidence interval, 1.6 to 2.7) the rate associated with spontaneous delivery but that did not differ significantly from the rate associated with vacuum extraction (odds ratio, 0.9; 95 percent confidence interval, 0.7 to 1.3) or forceps delivery (odds ratio, 0.7; 95 percent confidence interval, 0.4 to 1.1).

The rates of subdural or cerebral hemorrhage, facial-nerve injury, convulsions, central nervous system depression, and mechanical ventilation were significantly higher in infants delivered by cesarean section after a failed attempt at operative vaginal delivery (i.e., vacuum extraction, forceps delivery, or both) than in those delivered spontaneously (Table 2). As compared with vacuum extraction, cesarean delivery after a failed attempt at operative vaginal delivery was associated with significantly higher rates of subdural or cerebral hemorrhage, convulsions, and mechanical ventilation (Table 3). Intracranial hemorrhage occurred in 1 of every 334 infants delivered by cesarean section after a failed attempt at operative vaginal delivery, a rate that was 5.7 times (95 percent confidence interval, 2.5 to 12.5) the rate associated with spontaneous delivery, 2.6 times (95 percent confidence interval, 1.1 to 5.8) that associated with vacuum extraction, and 2.9 times (95 percent confidence interval, 1.2 to 6.4) that associated with cesarean delivery during labor with no attempt at operative vaginal delivery.

As compared with spontaneous delivery, cesarean delivery during labor with no attempt at operative vag-

inal delivery was associated with significantly higher rates of subdural or cerebral hemorrhage, intraventricular hemorrhage, convulsions, central nervous system depression, feeding difficulty, and mechanical ventilation (Table 2). Infants delivered by cesarean section during labor with no attempt at operative vaginal delivery had significantly higher rates of convulsions, feeding difficulty, and mechanical ventilation than did infants delivered by vacuum extraction (Table 3). Intracranial hemorrhage occurred in 1 of every 954 infants delivered by cesarean section during labor with no attempt at operative vaginal delivery, a rate that was 2.0 times (95 percent confidence interval, 1.5 to 2.6) the rate associated with spontaneous delivery but no higher than that associated with vacuum extraction (odds ratio, 0.9; 95 percent confidence interval, 0.7 to 1.3).

Infants delivered by cesarean section with no labor had significantly higher rates of central nervous system depression, feeding difficulty, and mechanical ventilation than did infants delivered spontaneously (Table 2). Intracranial hemorrhage occurred in 1 of every 2750 infants delivered by cesarean section with no labor, a rate that did not differ significantly from the rate associated with spontaneous delivery (odds ratio, 0.7; 95 percent confidence interval, 0.4 to 1.3) but that was significantly lower than the rates associated with vacuum extraction (odds ratio, 0.3; 95 percent confidence interval, 0.2 to 0.6), forceps delivery (odds ratio, 0.2; 95 percent confidence interval, 0.1 to 0.5), and cesarean delivery during labor (odds ratio, 0.3; 95 percent confidence interval, 0.2 to 0.6).

DISCUSSION

We found that the rates of intracranial hemorrhage were low with all modes of delivery but were higher with vacuum extraction, forceps delivery, and cesarean delivery during labor than with spontaneous vaginal delivery. The rates for the three types of operative delivery were similar. There was an incremental increase in the rate of intracranial hemorrhage if more than one method of delivery was used. The frequency of intracranial hemorrhage in infants born by cesarean delivery during labor with no attempt at operative vaginal delivery did not differ significantly from the frequency in infants born by operative vaginal delivery, and the frequency of hemorrhage was similar in infants born by cesarean delivery with no labor and those delivered spontaneously. These findings suggest that the method of delivery is not necessarily the primary factor associated with intracranial hemorrhage.

In a 1979 review of 15 studies involving a total of 7124 infants delivered by vacuum extraction with the Malmström extractor, the incidence of intracranial hemorrhage was 1 in 286 infants.[12] This rate is three times the rate in our study (1 in 860), probably because of the use of the metal Malmström cup, the longer period of neonatal observation (since maternal hospitalizations were longer), or the lower rate of cesarean delivery for fetal indications in the earlier era. The rate of intracranial hemorrhage decreased after the introduction of plastic cups for vacuum extraction. Since 1989, seven studies involving a total of 1265 infants have reported no intracranial hemorrhages,[18-24] findings that are consistent with the incidence of less than 1 percent in our study.

We are unaware of any study that has conclusively demonstrated that vacuum extraction is safer than forceps delivery or vice versa. In our study, the only substantial difference between them was that forceps delivery was associated with a higher rate of facial-nerve injury. This injury is caused by the pressure of the forceps blade on the facial nerve, and it is usually transient.

Since both vacuum extraction and forceps delivery involve placing an instrument on the head of the fetus, one would intuitively think that intracranial hemorrhage could be associated with vacuum extraction or forceps delivery but not with cesarean delivery. However, our study showed that cesarean delivery performed during labor, with or without a previous attempt at operative vaginal delivery, was associated with a higher rate of intracranial hemorrhage than was spontaneous vaginal delivery, whereas the rate of hemorrhage associated with cesarean delivery without labor did not differ significantly from the rate associated with spontaneous delivery.

Since cesarean delivery during labor was associated with increased rates of intracranial hemorrhage and other complications, a substantial proportion of the morbidity associated with operative vaginal delivery may be due to an underlying abnormality of labor rather than to the procedure. Most cesarean deliveries in nulliparous women are performed because of an arrest of labor, and operative vaginal deliveries are often performed after a long second stage of labor. Thus, the underlying risk factor may be a long, dysfunctional labor. Another confounding factor may be the position of the fetal head in the maternal pelvis. Operative delivery is often required when the head of the fetus is not descending through the pelvis correctly, because of either an oblique position or poor flexion. Thus, an intracranial injury associated with any type of operative delivery may be due to dysfunctional labor rather than to the operative intervention.

A strength of our study is that the data reflect the experience and skills of many practitioners. The results indicate that vacuum extraction and forceps delivery are associated with an irreducible component of morbidity among infants of normal birth weight, because the rate of intracranial injuries was not significantly lower in infants born by cesarean delivery during labor than in those delivered by vacuum extraction or with use of forceps. Other strengths are

the large size of the study and the accuracy of the data on discharge diagnoses in California, which are continuously reviewed and validated by the state.[25] Likewise, California birth certificates have been found to contain valid information.[26]

The limitations of our study are those inherent in a retrospective analysis. Without a systematic study of all infants, injuries may have been missed. We could not document readmissions due to injuries and may therefore have underestimated the true incidence of injuries. Since the study was limited to California, regional and perhaps other demographic factors may have affected the results. However, California is a diverse state, and deliveries in California account for 15 percent of all the deliveries in the United States. A major limitation is that risk factors for injury cannot be further identified, because the data base does not contain information about the indications for operative delivery, such as the duration of labor and the position of the fetal head. In the absence of this information and in view of clinicians' individual preferences in choosing the mode of delivery, the study groups may not be comparable, and the differences in morbidity therefore cannot necessarily be attributed to the mode of delivery.

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