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# Neonatal Morbidity and Mortality After Elective Cesarean Delivery

Caroline Signore, MD, MPH[a,*], Mark Klebanoff, MD, MPH[b]

[a]*Pregnancy and Perinatology Branch,* Eunice Kennedy Shriver *National Institute of Child Health and Human Development, National Institutes of Health, Department of Health and Human Services, 6100 Executive Boulevard, Room 4B03, MSC 7510, Bethesda, MD 20892, USA*

[b]*Division of Epidemiology, Statistics and Prevention Research,* Eunice Kennedy Shriver *National Institute of Child Health and Human Development, National Institutes of Health, Department of Health and Human Services, 6100 Executive Boulevard, Room 7B03, MSC 7510, Bethesda, MD 20892, USA*

The cesarean delivery (CD) rate in the United States reached 30.2% in 2005, an all-time high [1]. Several factors are contributing to this rise: an increase in the rates of first-time, or primary, CD coupled with a decrease in rates of vaginal birth after cesarean (VBAC) are believed major components. In addition to the growing numbers of elective repeat CDs, there is increasing attention to elective cesarean delivery (ECD) without medical or obstetric indications, which may be performed on maternal request. Clinicians and patients considering ECD should undertake a thorough discussion of the risks and benefits of planned ECD versus planned vaginal delivery as related to maternal and infant outcomes.

This article explores the effects of ECD on neonatal morbidity and mortality. Available data are subject to several limitations. There are no randomized trial data comparing outcomes among births from planned ECD versus planned vaginal delivery in otherwise uncomplicated pregnancies; it is possible that such a trial never can be accomplished. Furthermore, it has been difficult to identify and report rates of ECDs in many observational studies because this procedure option may not be included in hospital coding systems or among payers' reimbursable insurance claims. Thus, this

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* Corresponding author.
*E-mail address:* signorec@mail.NIH.gov (C. Signore).

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article focuses primarily on available data on neonatal outcomes associated with CD without labor, most commonly in the context of elective repeat cesarean and cesarean for breech, recognizing that data from these patient groups may not be fully generalizable to other types of elective CD (eg, CD on maternal request).

## Perinatal and infant mortality

For more than 15 years, United States vital statistics data have indicated a 1.5-fold increased risk for neonatal mortality after CD (planned and unplanned) compared with vaginal delivery, although this has been assumed the result of a greater proportion of high-risk pregnancies delivered operatively [2]. Data more specific to ECD in uncomplicated pregnancies are conflicting. In a meta-analysis of nine studies including more than 33,000 women, Mozurkewich and Hutton reported a significant increase in intrapartum and neonatal deaths among term, nonmalformed infants who underwent a trial of labor compared with those who underwent elective repeat CD (odds ratio [OR] 2.05; 95% CI, 1.17–3.57) [3]. A recent United States population-based study of neonatal and infant mortality by mode of delivery among women who had "no indicated risk," however, showed that neonatal mortality was increased more than twofold after birth by cesarean, even after excluding infants who had congenital anomalies and presumed intrapartum hypoxic events (Apgar score $<4$) and adjusting for demographic and medical covariates [2]. In these studies and others, the reported rates of neonatal death after elective repeat or "no indicated risk" cesareans are low, ranging from 0.01% to 0.17% [2–5].

When considering the risk for neonatal death after ECD, consideration should be given to the competing risk for fetal demise in an ongoing pregnancy. Many investigators have reported an increase in unexplained intrauterine fetal demise rates that begins near term and continues with advancing gestation [6–8]. Smith [9] calculated the cumulative probability of antepartum stillbirth as 0.08% at 38 weeks' gestation rising to 0.34% at 41 weeks' gestation.

In an attempt to reconcile the competing risks for neonatal death after ECD at term and antepartum stillbirth in ongoing term pregnancies, the authors [10] conducted a decision analysis, modeling the probability of perinatal death among a hypothetical cohort of 2,000,000 women who had uncomplicated pregnancies at 39 weeks, half of whom underwent ECD and half managed expectantly. After taking multiple chance probabilities into account, the model estimated that although neonatal deaths were increased among women delivered by elective cesarean, overall perinatal mortality was increased among women managed expectantly, because of the ongoing risk for fetal death in pregnancies that continue beyond 39 weeks. It was estimated that 1441 ECDs need to be performed to prevent one perinatal death (Table 1). In a separate analysis, Hankins and colleagues [7] reached a similar conclusion.

Table 1
Results of decision analyses comparing outcomes among 1 million elective cesarean deliveries and 1 million planned vaginal deliveries: estimated neonatal morbidity and mortality by management strategy

| | Elective cesarean delivery at 39 weeks | Expectant management | Number of cesarean deliveries needed to prevent one case[a] |
|---|---|---|---|
| Perinatal deaths | 804 | 1496 | 1441 |
| Stillbirths | 0 | 1118 | |
| Neonatal deaths | 804 | 378 | |
| Respiratory morbidity (TTN and RDS) | 11,000 | 2524 | |
| Intracranial hemorrhage | 490 | 1007 | 1934 |
| Brachial plexus injury | 410 | 787 | 2653 |
| PPH | 3700 | 1488 | |
| Suspected sepsis | 20,000 | 33,211 | 76 |
| Confirmed sepsis | 0 | 2635 | 380 |
| Laceration | 8000 | 2464 | |

Numbers shown are number of cases per million deliveries.

[a] Results shown only for those outcomes estimated to occur more frequently with expectant management.

*Adapted from* Signore C, Hemachandra A, Klebanoff M. Neonatal mortality and morbidity after elective cesarean delivery versus routine expectant management: a decision analysis. Semin Perinatol 2006;30:288–95; with permission.

Although this type of modeling is subject to limitations [10–13], elective delivery—by cesarean or induction of labor—of a healthy fetus at 39 weeks by accurate dating essentially eliminates the risk for future in utero fetal demise. There are three important caveats. First, the results of these analyses should not be taken as an impetus for elective delivery before 39 weeks. Neonatal deaths increase with each week of decreasing gestational age, such that by 37 weeks, the association between ECD and reduced perinatal mortality seems lost [10], and perinatal deaths may be expected to increase with surgical intervention (Fig. 1). Clinicians should adhere to American College of Obstetricians and Gynecologists (ACOG) practice guidelines for confirming gestational age (or lung maturity) before elective delivery [14].

Second, these analyses assume that a live-born infant whose impending stillbirth was prevented by ECD at 39 weeks has the same risk for neonatal mortality as an infant who would not have died in utero if managed expectantly. This assumption may not hold in reality, as a fetal condition that may predispose to stillbirth at 40 weeks similarly may predispose to neonatal death after a "rescue" delivery at 39 weeks.

Third, calculation of a number needed to treat assumes a causal relationship between exposure—in this case, mode of delivery—and outcome. This assumption also may be contested; existing observational data do not warrant the conclusion that the association between ECD and perinatal death (or other outcomes considered here) is causal. Similarly, it is delivery of an infant that prevents future stillbirth not ECD per se.

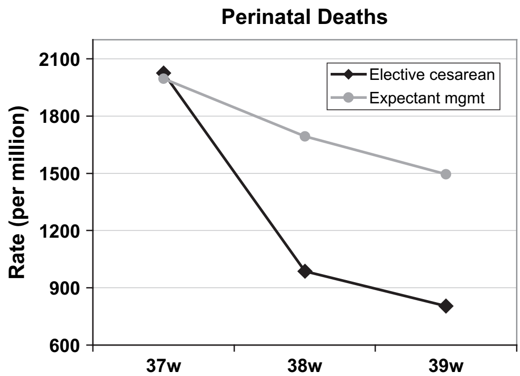


Fig. 1. Estimated perinatal deaths associated with ECD versus expectant management, by gestational age. Perinatal mortality increases for both modes of delivery as gestational age decreases below 39 weeks. At 37 weeks' gestation, more perinatal deaths would be expected with ECD than with expectant management. (*Adapted from* Signore C, Hemachandra A, Klebanoff M. Neonatal mortality and morbidity after elective cesarean delivery versus routine expectant management: a decision analysis. Semin Perinatol 2006;30:288–95; with permission.)

## Respiratory morbidity

Although characterized by varying definitions and methodologies, a consistent body of evidence indicates that infants delivered by elective cesarean experience higher rates of respiratory morbidity than infants delivered vaginally [15,16]. In term infants, respiratory difficulty is manifested most often as transient tachypnea of the newborn (TTN), although more serious disorders, such as respiratory distress syndrome (RDS) and persistent pulmonary hypertension (PPH), occur [17,18]. In a cohort study of more than 33,000 births between 37 and 42 weeks, infants delivered by prelabor cesarean (N = 2341) were nearly 7 times more likely to develop respiratory morbidity (RDS or TTN) than infants delivered vaginally (3.6% versus 0.5%; OR 6.8; 95% CI, 5.2–8.9) [19]. In this and other studies [20–22], the risk for respiratory morbidity in term infants is decreased with advancing gestational age. Hansen and colleagues [20] recently showed that infants delivered by elective cesarean at 37 weeks had a 10% incidence of respiratory morbidity (defined as TTN, RDS, or PPH) compared with 2.8% among infants delivered vaginally (OR 3.7; 95% CI, 2.2–6.1). By 40 weeks, the rate of respiratory morbidity with ECD decreased to 1.5% and no longer was significantly different from the rate seen with vaginal deliveries. Even among term infants, respiratory difficulty associated with ECD can be serious. In the Hansen study, 1.9% of infants delivered by ECD at 37 weeks experienced serious respiratory morbidity, defined as that requiring treatment for 3 days or more with continuous oxygen, nasal continuous positive airway pressure, or any period of mechanical ventilation [20].

Proposed mechanisms for the association between CD and respiratory morbidity include iatrogenic prematurity with surfactant deficiency [18,23] and an attenuation of the fetal catecholamine surge during labor [24,25]. Some [19,26], but not all [27,28], investigators report a decrease in respiratory morbidity if CD is performed after onset of labor. This has prompted some investigators to recommend deferral of ECD until after the onset of spontaneous labor [29].

As discussed previously, ACOG practice guidelines specify that without biochemical assessment of fetal lung maturity, elective delivery should not be undertaken before 39 weeks' gestation by strict criteria [14]. This recommendation was affirmed by an expert panel conducting the recent National Institutes of Health and Human Development State-of-the-Science Conference: Cesarean Delivery on Maternal Request [30]. A recent British randomized trial showed that a single course of antenatal corticosteroids before ECD at 37 weeks or later significantly decreased special care nursery admissions for respiratory distress (2.4% versus 5.1%; $P = .021$; relative risk 0.46; 95% CI, 0.23–0.93) [31]. The treatment effect was particularly pronounced at 37 to 38 weeks, but even with treatment, respiratory distress was substantially more common at these gestational ages than at 39 weeks or later. Again, delaying ECD until 39 weeks or later decreases rates of newborn respiratory distress, but steroids may be helpful in preventing respiratory complications in a fetus at 37 or 38 weeks with a nonimmediate indication for prelabor CD.

## Neonatal asphyxia or encephalopathy and permanent neurologic injury

Early advocates for ECD proposed that these "atraumatic" deliveries would decrease the risk for intrapartum neurologic injury and cerebral palsy [32]. Neonatal encephalopathy is a clinical syndrome of abnormal neurologic function in late preterm and term infants characterized by altered level of consciousness, abnormal muscular tone and reflexes, respiratory difficulty, or seizure activity [33]. Infants who have neonatal encephalopathy may or may not develop permanent neurologic impairment, such as cerebral palsy. Despite consistently rising CD rates over the past 3 decades, cerebral palsy rates in term ($\geq$2500-g) infants have not decreased [34], supporting the widely held premise that a minority of cases (approximately 10%) of encephalopathy and cerebral palsy in these infants are related to intrapartum hypoxic events, thus amenable to prevention by altering route of delivery [35,36]. Alternatively, in at least some cases, ECD at 39 weeks is expected to preempt an unpredictable catastrophic obstetric event (eg, acute placental abruption at 40 weeks) that might result in permanent neurologic injury.

Data addressing the impact of route of delivery on immediate and long-term neurologic outcome are sparse and conflicting. Badawi and colleagues [37] conducted a case-control study of 164 term infants who had moderate to severe newborn encephalopathy and 400 randomly selected control infants and found a lower risk for encephalopathy in infants delivered by elective cesarean (defined as CD planned at least 24 hours before surgery) than in those delivered via spontaneous vaginal delivery (OR 0.17; 95% CI, 0.05–0.56). Alternatively, Towner and colleagues [38] found higher rates of convulsions and central nervous system depression among infants weighing 2500 g to 4000 g delivered by cesarean without labor than in infants delivered spontaneously, although the difference was only significant for central nervous system depression (OR 2.2). A limitation of this study is that the ''cesarean without labor'' group likely included pregnancies with precarious maternal or fetal status, which would confound the relationship between mode of delivery and neonatal neurologic outcome [16]. Another consideration is that the vaginal delivery comparison groups in both studies consisted of actual spontaneous births, not all births from planned vaginal delivery, some of which would have been vacuum, forceps, and cesarean deliveries during labor. In the Badawi and Towner articles, rates of neonatal neurologic abnormalities were significantly higher in those delivered by operative vaginal delivery (OR 2.3–6.9) and CD during labor (OR 2.2–10.8) compared with spontaneous vaginal delivery [37,38]. If ECD prevents cerebral palsy, given that the United States rate of cerebral palsy is two to three per thousand and that 10% of cases arise intrapartum, approximately 3000 to 5000 ECDs would need to be performed to prevent one case of cerebral palsy related to labor events [10,32,39].

## Intracranial hemorrhage

Mode of delivery may be expected to influence rates of intracranial bleeding in neonates (ie, subdural or cerebral, intraventricular, and subarachnoid hemorrhage). Towner and colleagues [38] conducted a large, population-based retrospective review of more than 583,000 births of 2500- to 4000-g infants to nulliparous women in California and found a combined rate of intracranial hemorrhage of 0.4% among operative vaginal deliveries, 0.1% in CDs with labor, 0.05% in spontaneous vaginal deliveries, and 0.05% in CDs without labor. Although risk was significantly increased for operative vaginal delivery and CD during labor, there was no significant difference in the risk for intracranial hemorrhage between women who underwent prelabor CD and those who had a spontaneous vaginal delivery. These data suggest that intracranial hemorrhage may be related to underlying abnormalities of labor, as operative vaginal deliveries and labored CDs often are undertaken because of dysfunctional labor.

## Suspected and confirmed neonatal sepsis

Suspected neonatal infection is a major reason for admissions to neonatal intensive care units and invasive procedures in infants. Infection and inflammation are linked to higher rates of cerebral palsy [40,41]. There are scant data comparing rates of suspected and confirmed neonatal sepsis in infants delivered by ECD and by planned vaginal delivery. Hook and colleagues [42] compared infectious outcomes among 497 women undergoing elective repeat CD and 492 who attempted VBAC. Rates of suspected and confirmed neonatal sepsis were significantly lower in the elective repeat CD group (2% versus 5%, $P<.05$ for suspected sepsis, and 0% versus 1% $P<.05$ for proved sepsis). The rate of suspected sepsis was 12% in neonates born after a failed trial of labor compared with 2% after a successful VBAC ($P<.0001$). Based on these data, a decision analytic model estimated that evaluations for suspected neonatal sepsis would be decreased with a policy of ECD at term but that 380 ECDs would need to be performed to prevent one confirmed case of neonatal sepsis [10].

## Brachial plexus injury

Shoulder dystocia leading to brachial plexus injury remains a feared complication of attempted vaginal delivery. Shoulder dystocia remains difficult to predict, despite identification of risk factors, such as maternal diabetes, maternal obesity, and fetal macrosomia. Several studies have examined the potential benefit of prophylactic CD for preventing brachial plexus injury to a suspected macrosomic fetus [43–46], but there are few data regarding the impact of ECD on the rate of brachial plexus injury in nonmacrosomic infants. One large population-based study in California examined rates of brachial plexus injuries by mode of delivery in infants weighing 2500 g to 4000 g and found that compared with spontaneous vaginal deliveries, brachial plexus injuries were significantly less common in CDs (0.03% versus 0.08%; OR 0.4; 95% CI, 0.3–0.5) and significantly more common in operative vaginal deliveries (0.5% versus 0.08%; OR 6.0; 95% CI, 3.3–10.7) [38]. Brachial plexus injury occurred in 0.04% of CDs without labor; this rate was not significantly different from that of spontaneous vaginal deliveries (0.08%; OR 0.5; 95% CI, 0.3–1.0) [38].

## Fetal lacerations

That infants delivered by cesarean would be at risk for laceration from sharp instruments is intuitive and borne out in published reports. Fetal laceration occurs in 0.1% to 3.1% of CDs [47–52]. The risk for fetal laceration is greater during emergent (5.3%) and unscheduled labored CDs (1.8%) than in ECDs without labor (1.0%) [47,52]. Other risk factors for fetal laceration at CD are abnormal presentation [49,50] and rupture of membranes [52]. Although moderate to severe injuries requiring plastic surgical repair are reported, lacerations that occur during ECD usually are mild and rarely require treatment beyond application of sterile strips [47,52].

## Other outcomes

There are limited data examining other outcomes that may be influenced by ECD. Several investigators have expressed concern that CD, by separating mother and infant after birth, may have a negative impact on bonding and early initiation of breastfeeding [53]. In the Term Breech Trial, 77% of women randomized to planned vaginal delivery and 73% randomized to planned CD initiated breastfeeding "within a few hours" of delivery ($P = .05$) [54]. The median duration of breastfeeding was 8 months in both groups [55].

Another area of interest has been the "hygiene hypothesis" (ie, an alteration in microbial colonization of neonates not exposed to vaginal flora during delivery), which may affect postnatal maturation of T cells and predispose to illnesses later in childhood [56]. Several investigators have reported associations between CD and childhood asthma [57–59], but these findings have not been replicated in other studies [60–62].

## Summary

Increasing CD rates in the United States and worldwide are of intense interest and public health importance. Elective repeat CD rates have been increasing steadily since the late 1990s, and there may be a growing trend in CDs on maternal request. There are insufficient data on which to base conclusions regarding rates of neonatal morbidity and mortality between planned ECD and planned vaginal delivery. Nevertheless, existing data suggest that ECD is associated with greater risk for neonatal respiratory morbidity and fetal laceration and potentially decreased risk for brachial plexus injury, neonatal sepsis, intracranial hemorrhage, intrapartum asphyxia, and neonatal encephalopathy. Although neonatal deaths may be increased among infants delivered via elective cesarean, overall perinatal mortality may be reduced because of prevention of antepartum stillbirths. To minimize potential neonatal risks in ECDs, these deliveries should not be undertaken before 39 weeks' gestation. Patients considering ECD should be made aware of available data on potential risks and benefits to fetus and neonate. Further research is needed to inform these discussions.

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