

# Association of Catastrophic Neonatal Outcomes With Increased Rate of Subsequent Cesarean Deliveries

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**OBJECTIVE:** To evaluate whether full-term deliveries resulting in neonates diagnosed with hypoxic–ischemic encephalopathy are associated with a significant increase in the rate of subsequent unscheduled cesarean deliveries.

**METHODS:** We conducted a retrospective chart review study and examined all deliveries in the Department of Obstetrics and Gynecology at Hadassah University Hospital, Mt. Scopus campus, Jerusalem, Israel, during 2009–2014. We reviewed all cases of hypoxic–ischemic encephalopathy in singleton, term, liveborn neonates and identified seven such cases, three of which were attributed to obstetric mismanagement and four that were not. We measured the rate of unscheduled cesarean deliveries before and after the events and their respective hazard ratio.

**RESULTS:** Before a mismanaged delivery resulting in hypoxic–ischemic encephalopathy, the baseline rate of unscheduled cesarean deliveries was approximately 80 unscheduled cesarean deliveries for every 1,000 deliveries. In the first 4 weeks immediately after each of the three

identified cases, there was a significant increase in the rate of unscheduled cesarean deliveries by an additional 48 unscheduled cesarean deliveries per 1,000 deliveries (95% confidence interval [CI] 27–70/1,000). This increase was transient and lasted approximately 4 weeks. We estimated that each case was associated with approximately 17 additional unscheduled cesarean deliveries (95% CI 8–27). There was no increase in the rate of unscheduled cesarean deliveries in cases of hypoxic–ischemic encephalopathy that were not associated with mismanagement.

**CONCLUSION:** The increase in the rate of unscheduled cesarean deliveries after a catastrophic neonatal outcome may result in short-term changes in obstetricians' risk evaluation.

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Everyday experience as well as psychological research shows that outcomes of our decisions shape future actions. Specifically, it has been shown that the catastrophic event of uterine rupture in specific scenarios is associated with an increase in elective cesarean deliveries.<sup>1</sup> One interpretation of this result is that the catastrophic event per se changes physicians' decision-making process. Alternatively, the change in behavior could be the result of the association of the catastrophic event with the medical decisions that may have contributed to it. In the former case, the change in behavior is a form of associative learning; in the latter, it is a form of operant learning.<sup>2–4</sup>

To test these hypotheses, we considered hypoxic–ischemic encephalopathy<sup>5</sup> in full-term neonates. Hypoxic–ischemic encephalopathy is a catastrophic neonatal condition of acute or subacute brain injury secondary to asphyxia with an estimated incidence of 1.5 per 1,000 live births.<sup>6</sup> This condition can arise in labor while being associated or not being associated with obstetric mismanagement. Operant learning predicts

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a change in behavior only after mismanaged incidents. By contrast, associative learning suggests a change of behavior independent of the cause of the incidents. We compared the rate of unscheduled cesarean deliveries after cases, both associated and not associated with obstetric mismanagement, with the same rate preceding them. Specifically, we considered the following two questions: 1) Is there an increase in the rate of unscheduled cesarean deliveries after mismanaged hypoxic-ischemic encephalopathy deliveries? 2) If so, does a similar change in behavior occur after incidents not associated with obstetric mismanagement?

## MATERIALS AND METHODS

This retrospective chart review study was approved by the Ethics Committee of the Hadassah Medical Organization (Decision 0604-14-HMO). The study population was drawn from singleton, term liveborn neonates (gestational age 37 weeks or greater from last menstrual period) at Hadassah University Hospital, Mt. Scopus, Jerusalem, Israel. This tertiary care facility is one of two major hospitals serving a diverse population. We examined the records of all deliveries from February 2009 to November 2014. During this period, there were 26,320 deliveries: 19,910 (76%) of them vaginal, 3,819 (14%) elective cesarean deliveries, and 2,591 (10%) unscheduled cesarean deliveries. Elective cesarean deliveries included all cases of planned cesarean deliveries (repeat, maternal request, abnormal presentation and placentation). Unscheduled cesarean deliveries were defined as any unplanned, emergent cesarean deliveries, mainly the result of nonreassuring fetal monitoring or arrest of labor disorders. The database was obtained from the hospital's medical records department using International Classification of Diseases, 9<sup>th</sup> Revision codes. In Israel, standard obstetric practice consists of midwives and obstetricians, in which noncomplicated deliveries are handled by midwives with obstetricians present in the delivery room available to intervene if complications arise. The Mt. Scopus Obstetrics Department is comprised of 25 senior physicians, including four maternal-fetal medicine as well as 15 residents and 31 midwives.

Cases of hypoxic-ischemic encephalopathy were identified from the neonatal intensive care unit database. Seven cases of term neonates who developed hypoxic-ischemic encephalopathy in singleton pregnancies occurring between June 2010 and October 2013 were included. The average interval between the incidents was 206 days (range 8–515 days). A different obstetrician managed each case. A diagnosis of

hypoxic-ischemic encephalopathy was based on the criteria set by the American College of Obstetricians and Gynecologists.<sup>7</sup> All cases of hypoxic-ischemic encephalopathy that met study inclusion criteria were reviewed by study staff (D.H.-C. and A.S.) and divided, unanimously, into two groups based on etiology: 1) three cases of hypoxic-ischemic encephalopathy developed secondary to obstetric mismanagement (fetal heart monitor changes were not identified correctly); and 2) four deliveries complicated by hypoxic-ischemic encephalopathy not attributed to obstetric mismanagement (one case in which hypoxic-ischemic encephalopathy developed despite normal fetal monitoring throughout labor and delivery, two cases of fetal heart monitor changes occurring less than 5 minutes before delivery, and one case of difficulty in implementing neonatal resuscitation). No obstetricians or staff members underwent any disciplinary action related to these cases. Per hospital policy, all cases were reported to the risk management department for review within 7–10 days and proper changes, such as education regarding fetal monitoring, neonatal advanced cardiac life support, and proper standardization of equipment alarms, were instituted to prevent recurrence.

Our analysis focused on the change in the probability of a laboring woman undergoing an unscheduled cesarean delivery relative to a vaginal delivery in temporal association with a case of hypoxic-ischemic encephalopathy. To calculate this probability, we measured the change in the rate of unscheduled cesarean deliveries after a delivery complicated by hypoxic-ischemic encephalopathy and independently compared the rate of unscheduled cesarean deliveries in the 10-week period before and 6 weeks after each of the seven cases (Appendix 1, available online at <http://links.lww.com/AOG/A930>).

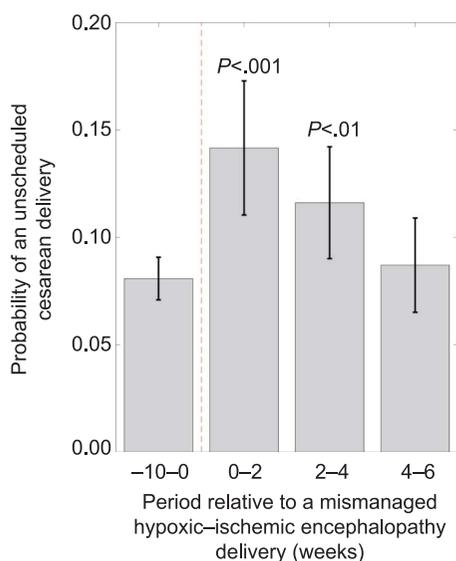
Changes in physicians' decision-making may be attributed to external factors unrelated to events in the hospital or in the professional environment. To control for these factors, we compared rates of unscheduled cesarean deliveries, in the corresponding time periods, with the rate of unscheduled cesarean deliveries in another branch of the hospital, Hadassah Medical Center, Ein Kerem, Jerusalem (supervised by the same administration and policies and sharing the same demographic population). This comparison did not reveal any significant change in the unscheduled cesarean delivery rate at this control hospital (Appendices 2 and 3, available online at <http://links.lww.com/AOG/A930>).

Data analysis and figure generation were performed using custom Matlab R2014b code.



## RESULTS

Of the 26,320 singleton term liveborn neonates in the study period (69 months), we identified seven term neonates from singleton deliveries complicated by hypoxic-ischemic encephalopathy, three of them associated with obstetric mismanagement and the remaining four cases not associated with obstetric mismanagement for an overall rate of 0.03%. To test the association of hypoxic-ischemic encephalopathy associated with obstetric mismanagement, with the rate of unscheduled cesarean delivery, we reviewed the deliveries in the 10-week period preceding these events and evaluated the rate of unscheduled cesarean deliveries (approximately 80 unscheduled cesarean deliveries for every 1,000 deliveries). Then, we reviewed the deliveries in the 6 weeks after each hypoxic-ischemic encephalopathy and computed the rate of unscheduled cesarean deliveries in blocks of 2 weeks (approximately 173 deliveries). We observed (Fig. 1) that the probability of unscheduled cesarean delivery significantly increased in the first 4 weeks after delivery of a neonate with hypoxic-ischemic encephalopathy resulting from obstetric mismanagement, resulting in 48 excessive unscheduled cesarean deliveries per 1,000 deliveries in that period (95% confidence interval [CI] 27–70/1,000,  $P < .001$ ). Considering each case of hypoxic-ischemic encephalopathy associated with obstetric mismanagement separately, we found



**Fig. 1.** The probability of unscheduled cesarean delivery. Red dashed line denotes the timing of hypoxic-ischemic encephalopathy events. Error bars indicate 95% confidence intervals.

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a significant increase in the rate of unscheduled cesarean deliveries in the 4 weeks after each of the incidents relative to the period preceding it ( $P < .05$ ).

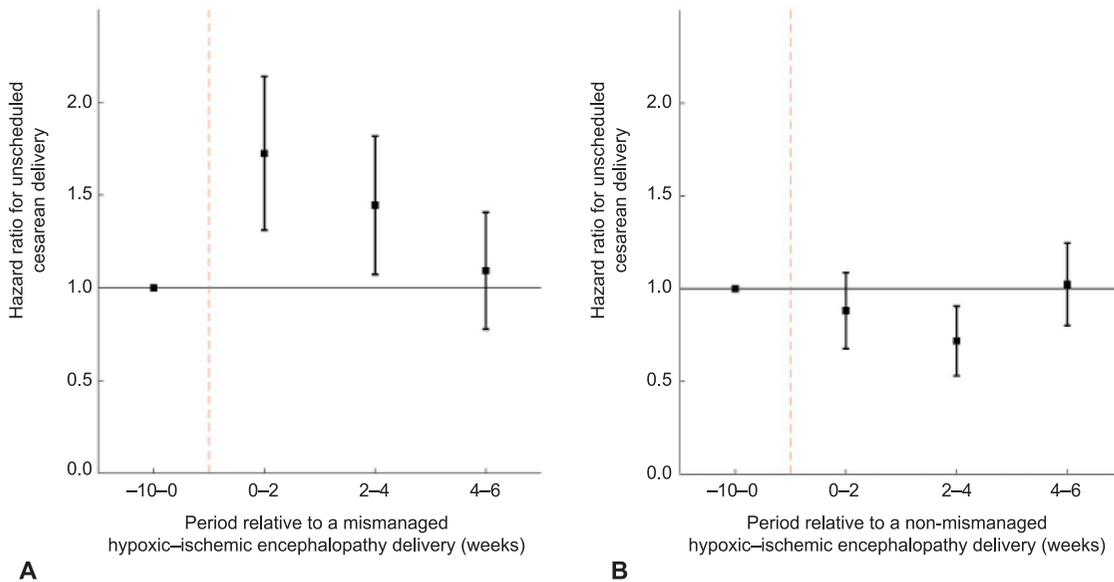
Another way of quantifying this change in behavior is to consider the hazard ratio (HR), the rate of change in the probability of unscheduled cesarean delivery. The HR of unscheduled cesarean deliveries in the first 4 weeks after an obstetric mismanaged hypoxic-ischemic encephalopathy was significantly greater than 1 (0–2 weeks: HR 1.72, 95% CI 1.31–2.21; 2–4 weeks: HR 1.45, 95% CI 1.07–1.88) but was not significantly different from 1 to 4 weeks (4–6 weeks: HR 1.09, 95% CI 0.77–1.46; Fig. 2A). To test whether the increased HR was associated with the outcome or with the presumed causative factors, we computed the HR of unscheduled cesarean deliveries after hypoxic-ischemic encephalopathy deliveries not associated with obstetric mismanagement (Fig. 2B). We found no significant increase in the rate of unscheduled cesarean delivery after these events (0–2 weeks: HR 0.88, 95% CI 0.67–1.11; 2–4 weeks: HR 0.72, 95% CI 0.53–0.93; 4–6 weeks: HR 1.02, 95% CI 0.80–1.27). In line with these results, a significant difference was found between the HRs of unscheduled cesarean deliveries after hypoxic-ischemic encephalopathy deliveries that were and those that were not associated with obstetric mismanagement in weeks 0–2 after the incidents ( $P < .05$ ), but not in weeks 2–4 ( $P < .1$ ) or 4–6 ( $P > .1$ ). In conclusion, the association between hypoxic-ischemic encephalopathy associated with obstetric mismanagement and a higher rate of unscheduled cesarean delivery persists for approximately 4 weeks (Figs. 1 and 2A).

To better quantify the dynamics of change in the rate of unscheduled cesarean deliveries after cases of hypoxic-ischemic encephalopathy associated with obstetric mismanagement, we used a method that is based on the cumulative sum of unscheduled cesarean deliveries (Appendices 4 and 5, available online at <http://links.lww.com/AOG/A930>). Based on this analysis, each case of hypoxic-ischemic encephalopathy associated with obstetric mismanagement was associated with approximately 17 additional unscheduled cesarean deliveries (95% CI 8–27).

## DISCUSSION

As with other medical specialties, obstetric practice may result in adverse outcomes despite the best care given.<sup>1,8</sup> However, not all obstetric catastrophic events occurring in the delivery room are associated with a change in future practice. When dividing hypoxic-ischemic encephalopathy cases by causative factor, obstetric mismanagement compared with





**Fig. 2.** **A.** Hazard ratios for unscheduled cesarean delivery after cases of hypoxic-ischemic encephalopathy associated with obstetric mismanagement. **B.** Hazard ratios for unscheduled cesarean delivery after cases of hypoxic-ischemic encephalopathy not associated with obstetric mismanagement. *Red dashed line* denotes the timing of hypoxic-ischemic encephalopathy events. *Error bars* indicate 95% confidence intervals.

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nonobstetric mismanagement, we found a substantial and significant increase in the rate of unscheduled cesarean deliveries after obstetric mismanagement. The increased rate of unscheduled cesarean deliveries was transient and reverted to its baseline rate approximately 4 weeks after the incidents. Repeating the analysis for hypoxic-ischemic encephalopathy deliveries not associated with mismanagement did not reveal a similar increase in the rate of unscheduled cesarean deliveries.

What is the cause of the change in behavior? It is important to note that the catastrophic outcome per se is not sufficient to change the practice, because the same fetal outcome is not associated with a change in subsequent behavior if it is not related to mismanagement. Therefore, the change in behavior cannot be attributed to outcome bias.<sup>9</sup> Rather, it is plausible that the interaction of the outcome and the sequence of events that led to it drive the change in behavior, such as in operant learning.<sup>10</sup>

Research suggests that preventable outcomes are a key factor in eliciting counterfactuals (ie, thoughts of how things might have been different),<sup>11</sup> which, in turn, may trigger more cautious behavior aimed at prevention of catastrophic events. We propose that in cases of obstetric mismanagement, physicians may feel that to prevent future unfortunate outcomes, they should overcompensate and choose a perceived safer modality of delivery such as cesarean delivery in bor-

derline cases in which under normal circumstances they would have proceeded with a spontaneous vaginal or instrumental delivery. In accordance with this hypothesis, when hypoxic-ischemic encephalopathy is not associated with obstetric mismanagement, it may be perceived as less preventable and hence no change in behavior is expected, as was observed in our study.

Why is the change in behavior transient? We hypothesize that the time-limited nature of the observed association with higher rates of unscheduled cesarean deliveries may be attributed to the psychological phenomenon known as “availability heuristic,” according to which event frequencies are evaluated “by the ease with which relevant instances come to mind.”<sup>12</sup> Hence, this bias predicts that more recent events would be judged as more frequent and more probable. In general, cesarean deliveries are considered a safer mode of delivery for neonates; therefore, they are performed more frequently in, for example, high-risk pregnancies and pregnancies resulting from in vitro fertilization and egg donation.<sup>13,14</sup> Thus, after an untoward neonatal outcome, it is understandable that physicians may opt for a cesarean delivery to minimize perceived risk. As the incident becomes more distant in time, it is perceived as less likely to recur, thus reverting the physicians’ risk assessment back to the baseline.

As a result of the rarity of neonatal hypoxic-ischemic encephalopathy as well as the practice



structure, our analyses were performed on the obstetrics department as a whole rather than addressing the physicians individually. However, all catastrophic events are reviewed and deliberated at daily staff meetings, for educational and training purposes, attended by all obstetricians. In this aspect, the change of behavior of the obstetricians is qualitatively different from standardly studied biases of choice that focus on how the actions of a human and their consequences affect subsequent actions of that subject.<sup>15-17</sup>

Our results suggest that mismanaged deliveries complicated by neonatal catastrophic outcomes may have a significant effect on future medical decision-making and may transiently influence the threshold for performing cesarean delivery. By acknowledging the interaction between event management and undesirable outcomes, health care providers may increase physicians' awareness to counterbias such effects and promote better and more uniform medical decision-making.

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