REVISITING INTRPARTUM PATHWAYS TO NEONATAL NEUROLOGIC INJURY – A LAWYER’S VIEW OF THE MEDICINE

By Richard C. Halpern
Partner
Thomson, Rogers
390 Bay Street, Suite 3100
Toronto, Ontario
M5H 1W2
rhalpern@thomsonrogers.com
416-868-3215

January 19th, 2015
Table of Contents

I. INTRODUCTION.........................................................................................................................1
II. THE OLD CRITERIA ..................................................................................................................4
III. INTRAPARTUM INJURY AND THE LAWYER.................................................................5
IV. TERMINOLOGY........................................................................................................................7
V. HYPOXIC-ISCHEMIC INSULT GENERALLY ........................................................................8
VI. NEUROIMAGING AND CAUSATION ...............................................................................13
VII. UMBILICAL CORD BLOOD GAS ANALYSIS .................................................................17
VIII. FETAL HEART RATE TRACINGS AND UTERINE CONTRACTIONS ......................22
IX. SENTINEL EVENTS................................................................................................................27
X. APGAR SCORING.....................................................................................................................28
XI. CEREBRAL PALSY AND NON-MOTOR DISABILITIES ..............................................28
XII. MULTI-ORGAN INVOLVEMENT .....................................................................................32
XIII. MECONIUM.........................................................................................................................33
XIV. THE 30-MINUTE RULE ....................................................................................................34
XV. DIFFERENTIAL DIAGNOSIS ..........................................................................................35
XVI. CONCLUSIONS....................................................................................................................35
I. INTRODUCTION

Impaired oxygenation (hypoxia-ischemia) to the fetal brain during labour and delivery (intrapartum) is an important cause of neurologic injury in the newborn. Determining whether neurologic injuries in affected babies may have been preventable by different intrapartum management of care begins by understanding the causal pathways to newborn neurologic injury. There are many variables to be considered in the causation analysis, including maternal factors, genetic issues, antenatal factors, intrapartum clinical data and neonatal clinical data. The subject is complex and not without controversy.

Not only has there been controversy surrounding the ‘science’ of the pathways to newborn neurologic injury, but the discourse has been tainted by bias.¹ For lawyers representing affected newborns, a successful claim requires establishing causation on a balance of probabilities, or more likely than not. For physicians defending these substantial claims, causation is vigorously challenged.

There is a considerable body of medical literature published on the issue, some with the professed objective of establishing guidelines to better understand these causal pathways. This paper will review some of the medical literature on the subject and important publications on the matter from the American College of Obstetricians and Gynecologists. At the outset, however, the reader must keep in mind that there are two variables in the causation analysis that provide the most objective evidence of an injury occurring at or around the time of birth: a particular topography of newborn brain injury on neuroimaging; and, umbilical cord blood gas analysis demonstrating a metabolic acidosis.

In 2003 the American College of Obstetricians and Gynecologists (ACOG) published a report called *Neonatal Encephalopathy and Cerebral Palsy: Defining the Pathogenesis and Pathophysiology*, the “old green book” or the “1st edition”. This report purported to, among other things, propound and justify certain criteria needed to connect poor neurological outcome in newborns to intrapartum events. In the old green book, ACOG sought to define criteria they deemed “essential” for making the causal connection between neurologic injury and intrapartum events. They also defined “non-essential” but highly suggestive criteria for making this causal connection. Physicians, lawyers and, ultimately, courts have placed considerable reliance on the old green book.

---

¹ Undoubtedly this article will attract that very criticism.
In a paper that I wrote in 2011[^3] I criticized the old green book based on what I considered flawed causation criteria. I argued that the scientific literature relied on in support of many of the critical conclusions made in the report did not, in fact, support those conclusions. In my paper I argued that the criteria established by ACOG have been used to avoid liability in birth trauma litigation. ACOG undertook a review of the old green book, which has taken a number of years to complete, and I had urged that the old green book criteria be withdrawn in the interim. This was not done.

In March 2014, ACOG finally delivered the second edition of the green book, with a new title: *Neonatal Encephalopathy and Neurologic Outcome*[^4]. There are important differences between the 1st edition and the 2nd edition that will be reviewed in some detail in this paper, revisiting some of the issues in my original paper.

At the outset, some observations about the new title are in order. The words “cerebral palsy” have been removed from the title. An essential criterion in the 1st edition, which I argued was not essential at all, was that cerebral palsy must be present in order to make the causal connection between newborn neurologic injury and intrapartum events. The scientific literature established that cerebral palsy is not an essential criterion for causation to be made out and the deletion of CP from the title is an acknowledgement of the shortcomings of the 1st edition, though very late in coming.

A further comment about the title should be made. While it refers to Neonatal Encephalopathy (NE) and “Neurologic Outcome”, a reading of the report demonstrates that it is less concerned about long term neurologic outcome and more concerned about the various causes for neonatal neurologic injury. It pays little attention to outcome beyond the neonatal period. It is a report primarily aimed at addressing causation for NE with the emphasis on pointing to causes other than Hypoxic-Ischemic Encephalopathy (HIE). This new report, like its predecessor, is focused on the prevalence of non-HIE causes for NE and one is again left with the impression that the objective is to diminish the importance of intrapartum events as a cause for NE.

Certainly ACOG is unapologetic for the shortcomings of the 1st edition. Without any acknowledgement of the serious flaws in the 1st edition, ACOG states the following in the second edition:

[^3]: The first paper I wrote was in July 2011, called *Newborn Neurological Injury: Medical and Legal Challenges to Causation*. My predecessor to this paper was called *Intrapartum Pathways to Neonatal Neurologic Injury - A Lawyer's View of the Medicine*. I have since revised that same paper in a number of ways for various audiences.

In the first edition of this guideline, the task force outlined criteria deemed essential to establish a causal link between intrapartum hypoxic events and cerebral palsy. For the purpose of the current edition, the task force determined that a broader perspective may be more fruitful. This conclusion reflects the sober recognition that our knowledge gaps still preclude a definitive set of markers that accurately identifies, with high sensitivity and specificity, an infant whose neonatal encephalopathy is attributable to an acute intrapartum event.5

One need not have a definitive marker to know that the former “essential” criteria were flawed at the time they were created. As will be seen below, the process is, and has always been, one involving the application of the differential diagnosis. That is, one must look at all the clinical data (antenatal, maternal, intrapartum, placental, neonatal) and determine the most likely cause or causes for newborn neurologic injury.

In 2005 a study by Miller et al considered the old green book criterion that neurologic injury that must result in CP of the spastic quadriplegic type in order to be causally connected to acute intrapartum events. Miller said:

Our clinical experience and data suggest that the outcome of neonatal encephalopathy is not homogeneous and may include cognitive deficits in the absence of cerebral palsy.6

While abandoning some of the core positions of the 1st edition, the preface to the 2nd edition bizarrely attempts to justify the assertions found wanting, when they assert that the old “essential criteria”, though not truly essential at all, “were useful for several reasons”.7 The justification for this position, while beyond the scope of this review, is groundless.

In my previous papers I have argued that the ACOG guidelines are motivated, at least in part, by the litigation process. Undoubtedly, the old green book has been used by some as a shield to avoid liability. To the extent that the old guideline was flawed, it has done a serious disservice. The new edition remains similarly tainted. The 2nd edition states:

Enhancing patient safety requires changing the culture of health care delivery from one that names and blames to one that is dedicated to

---

5 Supra note 4 at p. 207.
6 S. Miller, "Patterns of Brain Injury in Term Neonatal Encephalopathy" (2005), The Journal of Pediatrics, 146, 453-60 at p. 453
6 Supra note 4 at p. xix.
7 Supra note 4 at p. xix.
reducing medical errors through a constructive, nonthreatening, and professional process.\textsuperscript{8}

The notion that accountability for negligent errors is somehow incompatible with enhancing patient safety is a bald assertion without a sound foundation. This statement is entirely gratuitous and superfluous to the stated purpose of the report. It carries over a theme from the 1\textsuperscript{st} edition that tends to impair the credibility of the report. While the report chooses to call it “blame”, the fact is that proper allocation of the burden of loss, disclosure, personal responsibility, accountability and patient safety are at the core of the issue. It would be a mistake to entrust the improvement of patient safety to the internal operations of the medical profession without reliable and independent oversight. This is particularly so when obstetricians purport to establish rules, as the green book does, on matters that more properly belong in the realm of neurologists and neonatologists.

In the preface of the new green book the authors promise “a comprehensive multidimensional assessment tool of neonatal status to determine the likelihood that an acute hypoxic-ischemic event” contributed to neonatal encephalopathy.\textsuperscript{9} This was to be contained in chapter 13 of the report. The 2\textsuperscript{nd} edition has failed to deliver on this promise in any meaningful way.

This paper will touch on and repeat some of the important observations from my original paper. I will then review some of the important changes between the 1\textsuperscript{st} edition and the 2\textsuperscript{nd} edition of the green book. I will offer my conclusions on how lawyers conducting these cases ought to approach the causation issue based on my understanding of the medicine. I will conclude with some comments about the shortcomings of the 2\textsuperscript{nd} edition and future developments in the field.

\section{II. THE OLD CRITERIA}

The new green book has departed in important ways from the causation criteria of the old green book. The prior version set out 4 “essential criteria” for making a connection between newborn neurologic injury and intrapartum events. They were: evidence of a metabolic acidosis in fetal umbilical cord arterial blood (pH <7, Base Deficit >12); early onset severe or moderate neonatal encephalopathy; cerebral palsy of the spastic quadriplegic or dyskinetic type; and, exclusion of other identifiable etiologies.\textsuperscript{10}

The old green book also set out non-essential but suggestive criteria for causation, which included: a sentinel hypoxic event occurring immediately before or during labor; a sudden and sustained fetal bradycardia or the absence of fetal heart rate

\textsuperscript{8} Supra note 4 at p xix.
\textsuperscript{9} Ibid.
\textsuperscript{10} Supra note 4 at p. xicx.
variability in the presence of persistent late, or variable decelerations, usually after a hypoxic sentinel event when the pattern was previously normal; Apgar scores of 0-3 beyond 5 minutes; onset of multisystem involvement within 72 hours of birth; and, early imaging studies showing evidence of acute non-focal abnormality.

The new green book no longer explicitly stipulates “essential” criteria for proving a causal connection between neurologic injury and intrapartum events. Rather, the new publication describes the items to be included in the assessment of causation which references the old criteria, but in a less dogmatic way. The new green book has softened its approach to causation. It is my view that the ACOG approach to identifying causation has failed to put the emphasis in the right places with the effect of obscuring the causation analysis. The opportunity to provide valuable guidance regarding causation has been largely squandered.

III. INTRAPARTUM INJURY AND THE LAWYER

Newborn neurological injury due to trauma occurring in and around birth (peripartum) is often profoundly disabling. For affected infants and their families these injuries can be life-altering, resulting in unfathomable burdens. For health care professionals providing peripartum care, these dreaded outcomes are immensely distressing.

Neurological injury in infants may result from idiopathic causes, antenatal causes, unpreventable causes and potentially avoidable causes. The objective in the medical legal context is to distinguish between potentially avoidable causes and all other causes.

Lawyers representing children with suspected neonatal injury from peripartum events must have a thorough understanding of the pathways leading to these injuries in order to properly advance the interests of their clients. Only with knowledge of what causes newborn neurologic injury can one know what to look for, what questions to ask, and who to consult. Identifying the likely causal pathway to neonatal neurologic injury is challenging and at times controversial. When considering a cause for newborn neurologic injury that occurs in the intrapartum period the causes may include infection, hypoxia-ischemia and/or trauma.

The first step is to determine whether peripartum events are the likely cause of injury. Peripartum events may not be the sole cause of injury. Conventional medical thought focuses on hypoxia-ischemia (asphyxia) as the main cause of neonatal neurologic injury that may result in a compensable injury. Certainly these are the cases that tend to be pursued in our courts. Though less common, there may be other causes of neurologic injury giving rise to a cause of action. Trauma or any

11 Supra note 4 at Ch. 13, p.208.
event that tends to impair cerebral perfusion, including excessive “head compression” could be implicated as a cause for neurologic injury in the newborn.

Where clinical evidence points to an acute cause, the second step is to show how peripartum events led to the injury. The pathophysiology of peripartum neurologic injury is a matter of some controversy. In obstetrics, neonatology and neuroradiology there is disagreement regarding many of the medical issues that surround causation in the context of neonatal neurologic injury. Unfortunately, and unjustifiably, some of the thinking and science regarding causation has been influenced and distracted by concerns about legal liability.

Generally speaking, the importance of peripartum events in causing neonatal brain injury has been understated and underappreciated in the scientific literature. The failure to acknowledge the significant contribution of peripartum events to neonatal brain damage is most prominent in the obstetrical community. This is due, in part, to reliance on the old green book criteria.

It is well recognized in medical literature that neonatal encephalopathy (NE) can result from intrapartum events. The subset of NE attributed to intrapartum events is generally referred to as hypoxic-ischemic encephalopathy (HIE). Importantly, while HIE refers to both “hypoxia” and “ischemia”, it is ischemia that causes neuronal damage and consequent disability. Given that ischemia is a more important consequence of oxygen deprivation than hypoxemia, it is vital to appreciate the potential for intrapartum cerebral ischemia (with or without hypoxemia). Traditionally, much of the medical literature identifies the pathway to brain ischemia as one that inevitably passes through hypoxia leading to a metabolic acidosis. The developing metabolic acidosis may be followed by cardiac dysfunction that results in decreased cerebral perfusion (ischemia) which can lead to neurologic injury. Hypoxia-induced ischemia, with some exceptions, can be expected to be accompanied by a metabolic acidosis. The exceptions usually involve sentinel events, where there is not sufficient time for acidosis to develop, or where there is time for in utero resuscitation.

Thus, though not the central theme of this paper, it should be kept in mind that intrapartum threats to fetal wellbeing are not confined to hypoxia. Trauma and mechanical forces associated with labour, and the effect of these forces on the fetal head and cerebral blood flow (CBF), expose the fetus to risk of morbidity and mortality.

---

12 Volpe, J. *Neurology of the Newborn* 5th Ed, (Philadelphia: Saunders Elsevier 2008) at p. 331: “Among the many adverse consequences of the explosion in obstetrical litigation has been the tendency in some quarters of the medical profession to deny the importance or even the existence of intrapartum brain injury...this tendency is particularly unfortunate.”

13 Ibid. at p.247.
The main objective of monitoring of the fetal heart rate during labour is to assess the adequacy of fetal oxygenation through the identification of certain characteristics affected by hypoxic conditions. Where the intrauterine environment is hypoxic, there exists a risk of a developing metabolic acidosis that ultimately leads to ischemia and possible neurologic injury. Responding to fetal heart rate patterns suggestive of hypoxia and/or ischemia allows for intervention to avoid neurologic injury.

The conventional hypoxic pathway to intrapartum neurologic injury is focused on impaired gas exchange between the mother and the fetus. That impaired gas exchange can come in the form of factors that diminish utero-placental perfusion or factors that affect umbilical blood flow. This approach, however, will not account for the more direct impact of mechanical forces on the fetus affecting cerebral blood flow.

IV. TERMINOLOGY

The green book promotes the use of terminology that does not attribute a cause to the diagnosis. For example, the report prefers to describe a newborn as suffering from Neonatal Encephalopathy (NE) rather than Hypoxic-Ischemic Encephalopathy (HIE) or birth asphyxia. Where the cause of the NE is not known, and HIE does not appear on the available evidence to be likely, it is perfectly reasonable to expect the more general diagnosis of NE. On the other hand, HIE may well be the most appropriate working diagnosis based on the available clinical evidence. Moreover, as a matter of right, families are entitled to know if their baby’s NE is HIE. Further, HIE must be on the differential diagnosis, another bit of clinical information to which the family is entitled. The concern that HIE might connote some fault on the part of a member of the obstetrical team is in no way a reason to avoid the term. As the report goes to pains to show, not all HIE is due to substandard care. The new green book asserts that using NE rather the HIE is "important for families;" this is misleading in a clinical scenario where a peripartum event that creates hypoxia-ischemia is the cause of the encephalopathy.

A leading expert on neonatal neurology, Dr. Joseph Volpe, has written on this subject. Dr. Volpe has appropriately urged the use of the term HIE as a more precise diagnosis when the clinical circumstances suggest HIE. That is, when arterial cord blood analysis shows metabolic acidosis; when Apgar scores are depressed; when there is evidence of NE; and, where brain imaging topography is

14 Freeman, et al., Fetal Heart Rate Monitoring, 4th ( (Philadelphia: Lippincott Williams and Wilkins 2012) at)p.8.
15 Supra note 4 at p. 4.
that associated with hypoxic-ischemic insult. Dr. Volpe prefers to modify the diagnosis of HIE by referring to it as “presumed” or “apparent” diagnosis rather than use a less valuable clinical term like NE. Despite the overriding concerns of ACOG and others over legal liability, Dr. Volpe quite properly says:

…I believe that we have an obligation to provide the most accurate information that we can in a given infant concerning the nature and extent of neuropathology, the likely etiology, the most probable outcome, and the best available therapy. Thus, I feel strongly that neonatal HIE, and not a vague designation (NE) is the appropriate terminology for the encephalopathy described... (emphasis added)

As will be seen below, where neuroimaging points to a peripartum timing of injury, as it can, the likely cause of newborn encephalopathy is HIE. In those circumstances HIE is the appropriate diagnosis and should be used. The recommendations in the green book with regard to the use of terminology should have accorded with this clinical reality, but fail to do so. Promoting NE as the label for newborn outcome is a distraction from the real issues. There is no good reason to avoid or diminish the fact that hypoxia-ischemia is a cause for poor newborn neurologic outcome. Any attempt to do so merely impairs any notion of objectivity or patient safety as a primary focus. Further, the presence of HIE is not proof of substandard care; as such there is no valid reason for avoiding the use of the term HIE where clinically appropriate.

Unfortunately there is a considerable body of medical literature, including the green book, which attempts to diminish the importance of birth asphyxia as a cause for neonatal depression.

V. HYPOXIC-ISCHEMIC INSULT GENERALLY

Hypoxia-ischemia is preferred by some to describe what has been called asphyxia. The terms will be used interchangeably in this paper, but describe the scenario where there is an impairment of fetal gas exchange (oxygen in, carbon dioxide out) that results in impaired oxygenation to the fetus and increased carbon dioxide leading to a metabolic acidosis. When this occurs there is the risk of brain injury as well as injury to organs (including the heart, liver, kidney, etc.).

---

17 Ibid. at p. 157.
18 Ibid. at p. 162.
19 Ibid. at p. 163.
20 Nelson, K.B. "Causative Factors in Cerebral Palsy" (2008) Clinical Obstetrics and Gynecology 51:749-762 This paper, in my view, unduly diminishes the importance of intrapartum events as a cause of CP, not to mention the failure to recognize other non-motor disabilities caused by intrapartum hypoxia-ischemia.
It is well known that normal labour is associated with periodic decreases in fetal oxygenation and that the healthy fetus has considerable capacity to withstand periodic hypoxia.\textsuperscript{21} At the same time, the fetus exposed to antenatal stresses (i.e., due to maternal hypertension, reduced placental perfusion, or other issues) may not be as resilient and able to withstand the normal stresses of labour. Where there is evidence of antenatal complications, arguably the intrapartum tolerance for signs of fetal stress ought to be lower and intervention initiated sooner.

The key to fetal well-being is the maintenance of cerebral perfusion.\textsuperscript{22} Any process or mechanism that impairs blood flow to the fetal brain runs the risk of neurologic injury. Though the focus of the green book and much of the literature on the subject relates to hypoxia-ischemia leading to a systemic metabolic acidosis, presumably more direct mechanical forces on the fetal head might also impair cerebral perfusion without a systemic metabolic acidosis.

The ability of the fetus to compensate for hypoxic stresses during labour is generally considerable, but not unlimited. The purpose of monitoring the fetal heart rate is to watch for signs of hypoxic stress and to intervene before the ability of the fetus to compensate for hypoxia is overwhelmed.

The new green book identifies the challenge of attributing neurologic injury to intrapartum asphyxia as one of recognizing “a sufficient degree of asphyxia”, enough to overwhelm fetal compensatory mechanisms, “to cause these outcomes and rule out other causes”.\textsuperscript{23} This characterization of the search is destined to steer us in the wrong direction. The search for “sufficient” degrees of asphyxia to overwhelm the fetus is a futile one. First, if action is not taken until asphyxia is enough to cause NE and cerebral palsy, then there is no point in monitoring fetal well-being – you will be too late every time. Second, fetal tolerance for impaired oxygenation will vary.

There is considerable controversy regarding the incidence of HIE. According to Volpe (2012) between 50\% and 80\% of case of NE in neonatal intensive care units are thought to have HIE.\textsuperscript{24} Volpe also points out that despite challenges in determining the exact cause of brain injury shown on MRI, studies principally implicate the period just before or during labour and delivery.\textsuperscript{25}

Volpe’s leading text on neonatal neurology describes three features that point to intrapartum events as a likely cause of neonatal brain injury. This should be the starting point for any causation analysis and prompt investigation for a specific cause. The three factors are: evidence of fetal distress (e.g., abnormalities in the

\begin{footnotes}
\item[21] Supra note 4 at p. 21.
\item[22] Supra note 4 at Ch. 2 p. 4.
\item[23] Ibid. at Ch. 1 p. 2.
\item[24] Supra note 16 at p. 157.
\item[25] Supra note 16 at p. 160.
\end{footnotes}
Newborn neurologic injury can be due to antenatal factors, intrapartum factors, or a combination of the two.\textsuperscript{27}

Total asphyxia (i.e., from complete cord occlusion, cord prolapse, uterine rupture, etc.) causes a rapidly progressing hypoxia that results in brain injury after about 10 to 15 minutes.\textsuperscript{28} This type of insult is associated with a particular topography of brain injury to the thalamus and brain stem mostly.\textsuperscript{29}

Prolonged partial asphyxia, which may occur over hours, results in a different topography of brain injury. It will involve the cerebral cortex and white matter, in what has been described as a watershed distribution, as well as the basal ganglia.\textsuperscript{30}

Volpe also implicates the major pathogenetic cause of hypoxic-ischemic lesions in the brain as ischemia.\textsuperscript{31} This is an important observation as it raises the prospects that any mechanism that causes brain ischemia may result in the HIE topography of brain injury, but leaves open the question of whether a systemic metabolic acidosis must necessary accompany such an injury. This raises the prospect that mechanical forces on the fetal head that cause brain ischemia, or impaired cerebral perfusion, can occur independently of systemic metabolic acidosis.

The green book, and much of the available medical literature on the subject, are quick to point out two assertions that tend to attribute neonatal neurologic injury to causes other than acute intrapartum asphyxia: first, that the causes of NE are heterogeneous; and, second, that of all the causes, less than 10\% can be attributed to HIE. There is reason to doubt the second assertion. As will be seen in the section on neuroimaging and causation below, developments in MRI research demonstrates more neonatal brain injury due to acute intrapartum events than many publications allow.

A 2006 article by Gonalez and Miller states:

\begin{quote}
Hypoxic-ischaemic encephalopathy certainly accounts for a substantial fraction of neonatal encephalopathy... There is continuing controversy as to whether neonatal encephalopathy is primarily related to insults sustained in the antepartum or intrapartum
\end{quote}

\textsuperscript{26} Supra note 12 at p 401.
\textsuperscript{28} Supra note 16 at p. 158.
\textsuperscript{29} Ibid.
\textsuperscript{30} Ibid.
\textsuperscript{31} Ibid.
period...recent evidence from prospective cohorts of neonatal encephalopathy using magnetic resonance imaging (MRI) shows that most brain injury actually happens at or near the time of birth.\textsuperscript{32}

Gonzales and Miller, citing and contradicting the old green book, pointed out that an abnormal neurological examination early in life is the single most useful indicator that insult to the brain has occurred and can lead to abnormal neurodevelopmental outcomes that may or may not involve motor dysfunction.\textsuperscript{33}

An important article by Cowan addresses the timing of brain lesions in neonates with encephalopathy.\textsuperscript{34} This study looked at 351 full term infants born with NE, seizures or both. The first group included 261 infants with NE defined by:

1. Abnormal tone;
2. Feeding difficulties;
3. Altered alertness; and
4. At least three of the following:
   a. Late decelerations on fetal monitoring or meconium staining;
   b. Delayed onset of respirations;
   c. Arterial cord blood pH less than 7.1;
   d. Apgar scores less than 7 at five minutes; and
   e. Multi-organ failure.

The second group of 72 babies had seizures within 72 hours of birth, but did not meet the criteria for NE. There are important observations made about the first group in this study. These babies had NE in a clinical setting that clearly demonstrated intrapartum issues with fetal oxygenation. Where that sort of clinical evidence is present, the authors found that perinatal insults accounted for the overwhelming majority of neurologic injury in these babies. Of the 261 babies in the NE group, 80\% had acutely evolving brain lesions compatible with hypoxic-ischemic insult.\textsuperscript{35} MRI scans of 306 of the 351 babies studied showed evidence of acute findings only,\textsuperscript{36} indicating that recent insults were implicated in a considerable majority of the infants.

In the absence of specific syndromes or major congenital defects, Cowan found that more than 90\% of term infants with NE, seizures, or both, had evidence of perinatal

\textsuperscript{33} Ibid. at p. F455.
\textsuperscript{35} Ibid. at p. 737.
\textsuperscript{36} Ibid. at p. 738.
acquired insults, with few incurring brain injury before birth.\(^{37}\) This is not to say that antenatal factors might not predispose some fetuses to hypoxic-ischemic injury, a possibility not evaluated in the Cowan study.\(^{38}\) Having said that, the Cowan study takes issue with the assertion that only 8-15% of terms infants with NE have evidence of asphyxia before birth or that newborn signs of neurologic injury are more often the manifestation of more remote antenatal events. With respect to these assertions Cowan says, “**we have found little evidence for the two proposals that acute perinatal injury is uncommon in such infants, and that injurious processes have been taking place antenatally**”.\(^{39}\)

Subsequent to the Cowan study, Miller supported the conclusions regarding timing of injury in the Cowan study.\(^{40}\) Like the subjects in the 2003 Cowan study, the cohort in the 2005 Miller study demonstrated MRI findings consistent with recent injury, not chronic injury.\(^{41}\)

NE is a major cause of disability in term infants.\(^{42}\) To the extent that newborns with HIE represent an important subgroup of these affected infants, intrapartum asphyxia remains an important cause of disability.

A study by Martinez-Biarge (2013) looked at infants of more than 35 weeks gestation, born with a five minute Apgar score of <5 and/or an arterial cord pH of <7.1 and with NE. The study looked at 405 infants meeting these asphyxia criteria. HIE was mild in 15%, and moderate or severe in 77.5%. There was no information on severity for the balance of the cohort. This study found that when using a definition of NE that excludes babies with known antenatal or genetic problems, intrapartum events are the main contributors to HIE, not antenatal events.\(^{43}\) The authors found that intrapartum events commonly cause HIE. They did point out that there may be antenatal factors that create vulnerability to intrapartum hypoxia-ischemia.\(^{44}\) The authors concluded:

> Our results do not support the hypothesis that neonatal HIE starts antenatally, but point to the intrapartum period as the necessary factor for its development.\(^{45}\)

\(^{37}\) Ibid. at p. 740.

\(^{38}\) Ibid.

\(^{39}\) Ibid.


\(^{41}\) Ibid.

\(^{42}\) Ibid. at p. 453.


\(^{44}\) Ibid.

\(^{45}\) Ibid. at p. e958.
In any event, the assertion in the new green book that the clinical signs viewed as indicators of HIE have other causes that are more common\textsuperscript{46}, even if this assertion has any support in the literature, is a distraction from any meaningful diagnostic algorithm. The process, as will be described elsewhere, must rely on the differential diagnosis and begin with neuroimaging.

In the final analysis, acute intrapartum events are significant for causing neonatal neurologic injury. Where brain injury topography, dealt with below, and intrapartum and postpartum data are compatible with acute intrapartum injury, a very strong case is made for attributing brain injury to intrapartum events. This is so even if there are some antenatal circumstances that might predispose the fetus to hypoxic-ischemic injury. Working backwards, the first step in the causation analysis is to see if the newborn’s pattern of brain injury is compatible with acute intrapartum events.

VI. NEUROIMAGING AND CAUSATION

The focus of this review of neuroimaging and causation will be for the term baby. The topography of injury for the premature infant is different.\textsuperscript{47}

In my view, the causation analysis needs to begin with an assessment of the newborn brain using cranial ultrasound, CT scans and MRI. The 1\textsuperscript{st} edition of the green book did not, in my view, give neuroimaging the recognition it deserved in the causation analysis. The 2\textsuperscript{nd} edition does better, but still falls short.

In fact, ACOG seems to equivocate about the importance of neuroimaging, perhaps due to the impact of neuroimaging alone on the causation analysis and how it might diminish other long-held assertions advanced by ACOG. The new green book says:

\begin{quote}
Although challenging, neuroimaging may also be able to identify the timing and risk factors for acute brain injury in neonatal encephalopathy. It is, however, important to recognize that neuroimaging technique and their application to the newborn infant is a rapidly developing field.\textsuperscript{48}
\end{quote}

This passage simply does not give adequate recognition to the role of neuroimaging in the causation analysis. Neuroimaging is the single most important factor in identifying a cause for newborn neurologic injury. Any causation algorithm for the term newborn must begin with neuroimaging.

\textsuperscript{46} Supra note 4 at 3.
\textsuperscript{48} Supra note 4 Ch. 10 p. 149.
ACOG argues that the first step in the causation analysis requires that the newborn meet the definition of neonatal encephalopathy (NE). For the purpose of this paper it will be assumed that the causation analysis is applied only to the newborn with evidence of NE, the goal being to determine if the NE is due to hypoxic-ischemic encephalopathy (HIE).

My assertion that the causation analysis must begin with neuroimaging is supported by leading medical literature. Volpe (2012) states:

Neonatal HIE is a type of NE that is associated with a variety of clinical features and particularly a characteristic topography of acute lesions by MRI.

Cases of NE that might have previously been classified as idiopathic have become easier to classify based on advances in imaging. With MRI, the importance of perinatal hypoxia-ischemia as a cause for neurologic injury has been recognized. Moreover, the assertion that causes of NE are heterogeneous and more than 90% attributed to events other than intrapartum events, is undermined by the understanding of MRI studies. Volpe states:

In general, from 50 to 80% of NE cases in neonatal intensive care facilities are considered to have HIE, based on clinical, electroencephalographic (EEG), and MRI criteria.

With regard to brain injury, it is widely accepted that hypoxic-ischemic brain injury has a distinct pattern. The scientific literature establishes that the initial brain response to hypoxic-ischemic insult is edema or swelling, which tends to occur within 24 to 36 hours more or less, hitting its peak at between 38 and 72 hours following insult. Over the course of about 5 to 7 days the edema resolves, leaving the characteristic injury associated with hypoxic-ischemic injury.

Timing of injury to around the time of birth for babies with neonatal encephalopathy can be made due to the evolving pattern of brain injury shown on imaging that is consistent with more acute events, rather than remote antenatal

---

49 Supra note 4 at p. 208.
50 Supra note 4. As stated in the 2nd edition of the green book, at page 12, the pathway to HIE must progress through NE.
51 Supra note 16 at p. 157.
53 Supra note 14 at p. 157.
54 Supra note 4 at p. 209.
55 Supra note 12 at 349.
events.\textsuperscript{56} Far more newborns with NE have acquired their injury around the time of birth than the green book appears to be prepared to allow.\textsuperscript{57}

With regard to the value of neuroimaging in the causation analysis, the 2nd edition states:

\begin{quote}
Despite advances in neuroimaging, the ability to precisely time the occurrence (estimating within days rather than hours or minutes) of a hypoxic-ischemic event is still limited.
\end{quote}

This statement undervalues neuroimaging in timing injury. As important, this statement undervalues neuroimaging in ruling out more remote antenatal causes of neurologic injury. Later the new green book concedes the importance of neuroimaging in timing acute brain injury.\textsuperscript{58} There are three critically important findings that can be seen on imaging that will strongly suggest intrapartum timing. They are:

1. Early imaging (cranial ultrasound done in the first 48 hours of life) may demonstrate the absence of structural brain damage more remote than the peripartum period;

2. The onset of brain edema at about 24 hours of life, with increased edema resolving by 72 hours, points to an acute cerebral event;\textsuperscript{59}

3. The above criteria, when accompanied by brain injury confirmed on MRI at about 7 days of age, consistent with hypoxic-ischemic insult,\textsuperscript{60} almost certainly points to an acute intrapartum event.\textsuperscript{61}

In the presence of the 3 factors above, it is necessary to then evaluate whether there were any intrapartum clinical indicators of impaired fetal oxygenation and any newborn indicators pointing to impaired fetal oxygenation. In this setting, an acute intrapartum event becomes a very likely explanation for newborn neurologic injury. Importantly, in this context, other potential causes for neurologic injury become far less likely. This is not to say that co-morbid causes may not be at play or that some antenatal event or condition might have made the fetus more vulnerable to hypoxic-ischemic insult.

The literature has recognized distinctive patterns of brain injury associated with HIE. The patterns depend on the nature of the insult. Intrapartum hypoxic-ischemic insult can be due to a prolonged partial asphyxia that occurs over hours or days, a

\textsuperscript{56} Supra note 32 at p. F457.


\textsuperscript{58} Supra note 4 at p. 149.

\textsuperscript{59} Supra note 4 at p. 210.

\textsuperscript{60} Generally considered a bilateral watershed injury, and may include damage to the deep grey matter.

\textsuperscript{61} Supra note 4 at p. 154 for the evolution of neuropathology.
profound total or near-total asphyxia that occurs over minutes, or a combination of the two. The brain injury associated with a prolonged partial asphyxia is generally thought to be a watershed-distribution pattern that involves the white matter and cortical gray matter when severe.\textsuperscript{62} Mild to moderate hypotension for a period of time can cause injury to the parasagittal zones (called the “watershed areas”) that are perfused by the anterior, middle and posterior cerebral arteries.\textsuperscript{63} The damage to the cerebral cortex is more so in the subcortical white matter than the deep grey matter.\textsuperscript{64} The pattern associated with total or near-total asphyxia - although it can be present if prolonged partial asphyxia was ongoing for some time - is the basal ganglia-thalamus pattern involving the deep grey matter.\textsuperscript{65} This pattern is typically seen in the case of profound hypotension associated with a sentinel event.\textsuperscript{66}

By 7 to 10 days after injury neuroimaging will show the results of a resolving edema and brain damage evidenced by increase in the size of the ventricles with associated brain tissue death.\textsuperscript{67}

The presence of these well-recognized patterns of brain injury point strongly to a peripartum cause. This is why the causation analysis ought to begin with a review of the available neuroimaging. The presence of these patterns of injury following cerebral edema that has its onset and resolution within the timeframes described above establish the timing of injury, with reasonable certainty, to the peripartum period. Once this is done, the offending insult can be more precisely timed through the use of other clinical data.\textsuperscript{68}

Where the newborn has a basal ganglia/thalamus brain injury with relative sparing of the cerebral cortex, then one ought to suspect a sentinel event, such as severe cord compression, placental abruption, cord prolapse or uterine rupture, as the cause.\textsuperscript{69} In this scenario, umbilical cord blood gas analysis may not reveal a severe metabolic acidosis.\textsuperscript{70} Where there is bilateral involvement of the cerebral cortex in newborn brain injury, it points to a prolonged partial intrapartum asphyxia.

To summarize the importance of neuroimaging, the following can be said:

1. A large proportion of newborns born with NE acquired their brain injury in the peripartum period;

---

\textsuperscript{62} Supra note 4 at p. 152. See also Steinman, KJ, “Neonatal Watershed Brain Injury on Magnetic Resonance Imaging Correlates with Verbal IQ at 4 Years” Pediatrics; 123: 1611 at p. 1025.

\textsuperscript{63} Supra note 52 at p. 401.

\textsuperscript{64} Supra note 47 at p. 25.

\textsuperscript{65} Supra note 4 at p. 14.

\textsuperscript{66} Supra note 47 at p. 26.

\textsuperscript{67} Ibid at p. 27.

\textsuperscript{68} The new green book seems to concede the value of neuroimaging in identifying a window of opportunity for neurologic injury. See Supra note 4 at p. 115.

\textsuperscript{69} Supra note 16 at p. 161.

\textsuperscript{70} Supra note 16 at p. 161.
2. Where the topography of the injury is characteristic of hypoxia ischemia (either prolonged partial asphyxia, acute total asphyxia or a combination of the two) and where the injury evolves as hypoxic-ischemic injuries typically do, the insult occurred at or around the time of birth;
3. Whether antenatal factors or other complications (i.e., infection, growth issues, impaired utero-placental perfusion, etc.) made the fetus more susceptible to injury does not diminish the important of intrapartum causes.

Therefore, based on neuroimaging alone, a very strong case can be made for the timing of injury. Where neuroimaging points to events occurring at or around the time of labour and delivery, the next step is to look at the other available clinical evidence for more precision. But the inquiry becomes more about standard of care at this point and whether there were any intrapartum indicators that should have altered the management of intrapartum care. One should not assume that causation can be made out solely on neuroimaging; other variables, discussed below, factor into the analysis. In most cases, however, neuroimaging results are crucial to identifying the window of opportunity for injury. If that window is at or around the time of birth, most would consider the window to be up to 48 hours. More precision about timing must be established through other clinical evidence.

The new green book allows that timing based on neuroimaging can be reduce to a matter of “during labour or within days before labour and delivery”. As stated elsewhere, this also means that more remote antenatal causes are unlikely. It leads to the inevitable conclusion that some clinically important event occurred in the last couple of days of pregnancy. The objective must be discovering what the event was and when it happened.

VII. UMBILICAL CORD BLOOD GAS ANALYSIS

In the causation analysis, once neuroimaging confirms brain injury occurring within a 48 hour period around birth, the next variable to be looked at should be umbilical cord blood gases, particularly arterial. Arterial cord blood gas results can further refine the conclusions about timing of injury. It is known that low arterial pH in umbilical cord blood has a strong association with poor long-term outcomes. Base deficit is a calculated number that has a linear relationship to the accumulation of a metabolic acidosis and is a measure that can help in timing injury to the fetus.

71 Supra note 4 at Ch. 10 p. 163.
73 Supra note 4 at Ch. 6, p. 94.
Some preliminary observations about cord blood gas analysis are needed. First, care must be taken to ensure that a sample is taken from a cord artery and a sample from the vein. Second, care must be taken to ensure that the same vessel (usually the vein) is not sampled twice. Third, the lab results must be reviewed to ensure that the samples were not transposed. Finally, there are circumstances where relatively normal cord gas results do not rule out intrapartum asphyxia as a cause of poor neurologic outcome.\footnote{Supra note 70 at p. 830. Yeh recognizes the potential for some in utero recovery from hypoxia. Further, sentinel events resulting in acute total or near total asphyxia are not necessarily associated with poor cord gas results.}

The changes to the green book analysis of cord blood gas results are very important. Hypoxia can lead to a developing metabolic acidosis in the fetus that can, if it reaches critical levels, cause neuronal injury.\footnote{Supra note 4 at p. 94.} The 2\textsuperscript{nd} edition points out that most cases of cerebral palsy do not involve babies that are severely acidotic at birth,\footnote{Ibid.} the implication being that events other than peripartum events caused the CP. Often that is the case, but not necessarily so. There are occasions where the cord blood will not show severe metabolic acidosis even though the injury was intrapartum.\footnote{Pomerance, Jeffrey \textit{Interpreting Umbilical Cord Blood Gases: For Clinicians Caring for the Fetus Or Newborn}, (Glendora, Beverly Newborn Medical Group, Incorporated: 2012) at p. 6.} The report goes on to say that most severely acidic babies do not develop CP, which is largely irrelevant to the causation analysis. With regard to this comment, it is known that severe acidosis is a risk factor for neurologic injury (including, but not limited to, CP) and that severe acidosis points to an intrapartum timing for injury.

With regard to cord blood pH, the new green book states that a fetal umbilical arterial pH of less than 7.0 “increases the probability that neonatal encephalopathy” had an intrapartum component and that lesser degrees of acidemia decrease that likelihood.\footnote{Supra note 4 at p. 209.} The new edition goes further to say that a cord arterial pH above 7.2 indicates that intrapartum asphyxia was unlikely a cause for NE.\footnote{Ibid.} According to the old green book, an arterial cord blood pH of less than 7.0 was “essential” to make out causation.\footnote{Supra note 2 at p. 1056.} Obviously this represents a significant change.

A 2012 study found that the risk of an adverse neurologic outcome begins to rise below a pH of 7.1, with the risk rising sharply when pH is below 7.0.\footnote{Supra note 72 at p. 826.} At the same time, this study recognized a “small increase in adverse sequelae with higher pH levels.\footnote{Ibid.}
With regard to cord arterial base deficit, in the new green book a value greater than or equal to 12 mmol/L “increases the probability that neonatal encephalopathy” had an intrapartum component and that lesser degrees of acidemia decrease that likelihood. In the old green book a base deficit of 12 or greater was “essential”. In the new green book acidemia is demonstrated in cord arterial blood with a pH less than 7.0 or a base deficit of 12 or more. In the old green book you needed both as essential to proving causation. The following observations are important:

1. If either pH or base deficit demonstrate sufficient acidemia, the cause of NE is likely due to acute intrapartum events;
2. Even pH values up to 7.2 are now admitted to be compatible with acute intrapartum events;\(^{84}\)
3. Cord pH above 7.2 or a base deficit under 12 are not necessarily incompatible with an intrapartum cause.

With regard to base deficit, the new green book says:

...base deficit, a calculated value derived from the measured values of pH and pCO2 in blood, does have a linear relationship to the accumulation of lactic acid and, thus, also correlates with the risk of newborn neurologic injury, especially when it becomes severe (base deficit greater than 12 mmol/L).\(^{85}\)

With regard to pH, the new green book acknowledges that less severe acidosis levels indicated by a pH greater than 7.0 may be predictive of neonatal morbidity.\(^{86}\) A 2012 study by Yeh\(^{87}\) et al had a pH threshold “where the risk of adverse neurological outcomes rises significantly” of 7.10. Again, this does not mean that pH values over 7.10 are incompatible with intrapartum injury.

As I have stated, there are cases of intrapartum injury associated with an umbilical pH of greater than 7.0 and a base deficit less than 12 mmol/L. These occur most often following a sentinel event, like a cord prolapse or a uterine rupture.\(^{88}\)

The 2\(^{nd}\) edition also emphasizes that the presence of metabolic acidemia does not tell us the timing of the hypoxic-ischemic event.\(^{89}\) That comment is too imprecise to be of any value. I suggest that some conclusions about timing of the hypoxic-ischemic event can indeed be drawn from the presence and severity of metabolic...

\(^{83}\) Supra note 4 at p. 209.
\(^{84}\) Studies have shown that adverse outcomes increase at a pH 7.20 and lower: Graham, E. et. al, "A systematic Review of the Role of Intrapartum Hypoxia Ischemia in the Causation of Neonatal Encephalopathy" (2008) American Journal of Obstetrics and Gynecology 587-595 at p. 588.
\(^{85}\) Supra note 4 at p. 94.
\(^{86}\) Supra note 4 at p. 97.
\(^{87}\) Supra note 72.
\(^{88}\) Supra note 4 at p. 97.
\(^{89}\) Supra note 4 at p. 209.
acidemia. Very severe acidemia is unlikely to be tolerated for very long without fetal demise. Further, there are studies that show the rate of change of the base deficit under conditions of either prolonged partial asphyxia or profound total asphyxia that can be applied to help with timing.\(^90\) As well, considering the degree of acidemia in view of the intrapartum data (particularly periodic changes in the FHR patterns) will allow inferences to be drawn about timing. Finally, the presence of a severe metabolic acidosis (when accompanied by compatible neuroimaging and other data) will strongly point away from an antenatal or other cause of neurologic injury and will strongly suggest an acute intrapartum event to explain NE.

The critical point to make about evidence of metabolic acidosis in cord blood is that, if present, it indicates, unequivocally, that the fetus suffered hypoxic insult at or around the time of birth. It does not mean the baby will necessarily suffer from permanent neurologic injury, but only that during labour there were hypoxic insults. Further, it does not rule out other comorbid causes for neonatal depression. At the same time, the absence of a metabolic acidosis does not mean that the fetus was free from intrapartum hypoxia-ischemia or ischemia alone. In the end, evidence of metabolic acidosis in umbilical cord blood is objective evidence of intrapartum hypoxia-ischemia\(^91\) The absence of a metabolic acidosis (or where cord blood gases are unavailable) means that other clinical evidence must be relied upon to determine causation.

It follows that babies with neurologic injury likely suffered all or part of that injury from events occurring at or around the time of birth when supported by evidence of a sufficiently severe metabolic acidosis. Where, at the same time, the neuroimaging shows a topography of brain injury compatible with prolonged partial asphyxia, near total asphyxia, or a combination of the two, then it follows that intrapartum events likely explain part or all of the neurologic injury. As the pH drops below 7.0 the likelihood of significant sequelae from intrapartum hypoxia-ischemia increases.\(^92\)

Likewise, a base deficit of 12 mmol/L or higher is objective evidence of hypoxic insult occurring at or around the time of birth.\(^93\) When present, it strongly points to an intrapartum cause for neonatal depression. Like pH, a base deficit under 12 mmol/L does not rule out an intrapartum cause for the depressed neonate.

The diagnosis of acute intrapartum asphyxia resulting in neurologic injury can be made without the benefit of umbilical cord gas results or in the setting of relatively


\(^92\) Ibid.

\(^93\) Ibid. at 592.
normal results. Medical literature supports the notion that where other indicia strongly pointing to acute intrapartum asphyxia, the existence of normal cord gas results would not require a reconsideration of the diagnosis. Rennie et al (2008) points out that some cord blood samples are labeled arterial when they are venous; including abnormal cord gases as essential to diagnosis ignores the possibility for incorrect sampling; and, requiring abnormal cord gas results ignores the situation where the cord is totally occluded.

Intrapartum resuscitative measures (i.e., stopping oxytocin, maternal position change, etc.) can stop and even reverse a developing metabolic acidosis. There is literature to suggest that restoration of normal fetal pH values can be achieved in 40 to 60 minutes with fetal oxygen saturation improving progressively once the cause of hypoxia is mitigated. Thus, there may be scenarios where the umbilical cord blood gas numbers are not “bad” enough to suggest intrapartum timing, yet the timing is indeed intrapartum, but there has been some degree of in utero recovery from hypoxia. Other scenarios where intrapartum injury occurs without really “bad” gases are where a sentinel event occurs (like a shoulder dystocia) or where an acute total or near total asphyxia is superimposed on a previous prolonged partial hypoxia that had resulted in a building acidemia that had not yet reached the threshold for injury.

One should also allow for circumstances that impair cerebral perfusion or trauma without a systemic metabolic acidosis. In some situations there can be mechanical stresses that locally affect cerebral perfusion, such as in the case of a shoulder dystocia or excessive uterine activity causing head compression. A study by Yeh in 2012 concluded that “normal cord gases, therefore, are not entirely incompatible with brain hypoxia...”. Another important point made by the same authors is that a combination of risk factors may result in an injury without reaching what some consider the acceptable threshold of acidemia for injury. Yeh concludes:

Intrapartum fetal surveillance that relies almost entirely on detection of acidaemia...will lead to both a failure to prevent most adverse neurological outcomes and a high obstetric intervention rate. If other intrapartum deleterious processes are involved these further influence the degree of acidaemia that is tolerated, then a better understanding of these processes is urgently required, as is a more sophisticated way of using and interpreting pH.

94 Supra note 52 at p. 399.
95 Ibid. at p. 399.
97 Supra note 72 at p. 830.
98 Ibid at p. 830.
99 Ibid.
100 Ibid. at 830. The example used by Yeh is hypoxia combined with chorioamnionitis.
101 Ibid.
These important words highlight: the importance of not relying too heavily on cord blood gas analysis to arrive conclusively at an explanation for poor neurological outcome; and, the importance of recognizing other factors (antenatal and intrapartum, including mechanical forces on the fetal head affecting cerebral perfusion) that can diminish fetal tolerance for intrapartum asphyxia.

The new green book concedes that there are clinical circumstances where acute injury can occur with relatively good umbilical cord gas results (a pH > 7.0, a base deficit < 12). These are often associated with events that cause a sudden interruption of cerebral perfusion like a shoulder dystocia, a cord prolapse or a uterine rupture.102

VIII. FETAL HEART RATE TRACINGS AND UTERINE CONTRACTIONS

At the outset it is important to clearly understand the purpose of electronic fetal heart rate monitoring (EFM). EFM is not to be used to determine when the fetus becomes overwhelmed by impaired oxygenation leading to a metabolic acidosis severe enough to cause neurologic injury.103 Rather, EFM must be used to identify the fetus exposed to potentially damaging hypoxia so that intervention can occur before injury. Thus, the efficacy of EFM cannot be challenged by assertions that it does not help to predict the incidence of cerebral palsy. Many studies of EFM have inappropriately set the objective of determining whether certain fetal heart rate patterns identify a fetus with a metabolic acidosis and HIE.104 EFM would be of no value to intrapartum care if it was used to identify children with HIE.

Care must also be taken when considering medical literature that purports to comment on the efficacy of EFM and the prevailing nomenclature used to categorize tracing patterns. One must avoid blind faith in many of the conclusions drawn in these studies and question the validity of their conclusions in actual clinical practice.105

102 Supra note 4 at Ch. 6, p. 97.
103 Supra note 91 at, p. 586 , where it is noted that EFM has been shown to be very imprecise in detecting HIE, but that is not its purpose. We don't want to know when the fetus has HIE, we want to know when the fetus is at risk for HIE.
105 For example, a study by Cahill (Cahill, A. et. al. “Association and Prediction of Neonatal Acidemia”) American Journal of Obstetrics and Gynecology 207:206.e1-8.purported to examine the association between EFM patterns and neonatal acidemia. The study only looked at the last 30 minutes of tracing and did not consider the broader clinical picture. Intrapartum management of care, in my view, requires a careful assessment of the entire clinical picture. Selectively using part of the picture will not allow any reliable conclusions to be reached.
In particular, assertions that EFM has not resulted in a decline in the rate of CP and has resulted in an increased cesarean section rate are not an argument against the efficacy of EFM. At least some publications have acknowledged that the nature of the available data does not necessarily allow a full appreciation for the value of EFM. One such publication references two studies to suggest that a review of cases with poor outcomes repeatedly demonstrates that abnormal fetal heart tracings were misinterpreted and intrapartum care consequently poorly managed. Moreover, it is no coincidence that EFM is the most common form of intrapartum fetal surveillance and that EFM is mandatory when there is concern for increased risk to fetal wellbeing. There are two fundamental facts regarding EFM that are paramount: first, hypoxic insults and injury can occur in labour; and, second, the fetus experiencing hypoxic insults will inevitably demonstrate those on EFM.

There are intrapartum periodic changes in the fetal heart rate that are known to be associated with interruption of oxygen supply to the fetus. Decelerations in the FHR indicate hypoxia. The timing of decelerations in relation to uterine contractions is of critical importance in recognizing the significance of the hypoxic episode. Where there are repeated patterns suggesting concern for fetal well-being, there is the risk of producing a metabolic acidosis which, if it becomes severe enough, can lead to brain damage.

The new green book has recognized the importance of FHR monitoring as a tool to “prevent” asphyxial injury. Yet, despite this comment, the new green book seems to diminish the importance of continuous Electronic Fetal Heart Monitoring (EFM) by citing the absence of literature to support the ability to predict neurologic injury using this important tool. Over the years some authors have challenged the efficacy of EFM as it is a poor predictor of CP. This betrays a fundamental misunderstanding of the purpose of EFM. As stated above, EFM is not about predicting CP, but about developing an understanding about how well the fetus is coping with the stress of labour and ensuring that intervention occurs before the coping ability is overwhelmed.

---

107 Ibid. at p. 11.
108 In other words, a completely normal tracing indicates a well-oxygenated fetus. Intrapartum hypoxic insults will be reflected by periodic changes in the fetal heart rate. See Murray D., et. al. “Fetal Heart Rate Patterns in Neonatal Hypoxic-Ischemic Encephalopathy: Relationship with Early Cerebral Activity and Neurodevelopmental Outcome” (2009) Am. J. Perinatology 26:605-612 at p. 606. It is noted that a normal tracing is “highly predictive of a normal outcome”. I would point out that the exception to this would be where antenatal events are the sole cause of a bad outcome.
109 Supra note 4 at p. 88.
110 Supra note 4 at p. 91.
In 2007 The Society of Obstetricians and Gynecologists of Canada (SOGC) introduced new guidelines for antepartum and intrapartum fetal surveillance. Intrapartum tracings are to be divided into three categories: normal tracing; atypical tracing; and abnormal tracing. With a normal tracing monitoring may be interrupted for periods of up to 30 minutes. If the tracing is atypical, “further vigilant assessment” is required, particularly when combined atypical features are present. In the setting of abnormal tracings, review of the overall clinical situation is required and preparation for delivery or a scalp pH if appropriate is needed.

The ACOG guidelines on fetal heart rate interpretation divide tracing characteristics into three categories: I, II and III. Under the ACOG guidelines:

- Category I tracings are those strongly predictive of normal fetal acid-base status at the time of observation;
- Category II tracings do not meet the criteria for inclusion under Category I or III;
- Category III tracings identify fetuses at increased risk of abnormal fetal acid-base status at the time of observation.

The characteristics assigned to these three categories are problematic, but a review of the issues with fetal heart tracings is beyond the scope of this paper. It is sufficient to point out that Category I tracings are not terribly controversial and do not become an issue in litigation. The same cannot be said about Categories II and III. A fetus suffering from intrapartum episodes of hypoxia will not fail to demonstrate this on the fetal heart tracing. Category II is particularly problematic, and the new green book concedes that there is need to refine the management of Category II tracings.

The fetal heart tracing is a vital piece of causation evidence that helps narrow the timing of neurologic injury in the intrapartum period when other data (i.e., neuroimaging, cord blood gases, neonatal data, etc.) points to an intrapartum cause.

Fetal heart rate variability can be an indicator of impaired oxygenation and the presence of average variability may be an indicator of an intact central and peripheral nervous system. As such, changes in fetal heart rate variability may be helpful in timing intrauterine neurologic injury. It has been shown that

---

112 Ibid. at p. S37.
113 Supra note 4 at p. 89.
114 Supra note 4 at p. 107.
minimal/absent variability for one hour or more, particularly when combined with late decelerations, is a predictor of fetal acidemia.116

Certain fetal heart rate patterns are associated with hypoxia. Late decelerations may reflect reduced utero-placental perfusion as a response to uterine contractions that cause transient hypoxia.117 The literature demonstrates that late decelerations occur before acidemia and that variability reduces as acidemia increases,118 which supports the notion that intervention in the presence of abnormal fetal heart rate patterns can allow intervention before HIE develops.

All information about periodic changes in the fetal heart rate pattern must be evaluated in the context of the entire clinical picture. To isolate fetal heart patterns and attempt to identify those that might identify a neurologically injured fetus is folly. On the other hand, periodic changes known to be associated with hypoxia are much better appreciated when considered in relation to maternal health (i.e., blood pressure, diabetes, preeclampsia, etc.), antenatal history (i.e., fetal growth, IUGR, gestational age, etc.), uterine contraction patterns (i.e., particularly when labour is augmented or induced with oxytocin) and the progress of labour.

Uterine activity is a very important factor in assessing the significance of periodic changes in the FHR and the impact on fetal oxygenation.119 Tachysystole, or overly frequent contractions, may tend to cause fetal reserve to be exhausted more quickly. Studies show that increased uterine activity in both the first stage and second stage of labour increases the risk of fetal acidosis.120 Excessive uterine activity is more than just contractions occurring too frequently – it is also hypertonus, defined as contractions lasting more than 2 minutes, or contractions occurring within 60 seconds of each other.121 Even in the absence of fetal heart rate abnormalities, excessive uterine activity requires a clinical response (often by reducing oxytocin in augmented labours).

In a 2008 publication122 ACOG called for abandoning the terms “hyperstimulation” and “hypercontractility” in favour of using “tachysystole”. In this document, tachysystole is defined as more than 5 contractions in 10 minutes, averaged over a 30 minute period.123 Yet, a 2008 article by Simpson124 found a significantly higher

---

116 Ibid. at p. 301.e7.
117 Ibid. at p. 301.e6.
118 Ibid. at p. 301.e7.
120 Ibid. at p. 313.e5.
121 Supra note 106 at p. 19.
123 Ibid. at p. 662.
incidence of neonatal acidemia in labours where contractions were 5 or more in 10 minutes during the last hour of the first stage of labour or 5.5 contractions in 10 minutes in second stage labour. The real clinical issue with potentially abnormal uterine activity is its effect on fetal oxygenation. Fetal heart rate response to uterine activity, under either definition, is an indication of the ability of the particular fetus to cope with the stress of the uterine contraction frequency. As well, contraction duration is undoubtedly a variable that ought to be factored in. Evidence of frequent contractions and potentially impaired fetal oxygenation (diminished variability, late decelerations, tachycardia, etc.) should influence the clinical management of uterine activity, particularly in the setting of augmentation with oxytocin. Simpson observed that adverse fetal effects from tachysystole may be avoided by minimizing excessive uterine activity before the FHR pattern reflects some fetal intolerance. This is because their study showed that fetal oxygen desaturation began shortly after excessive uterine activity and before any non-reassuring FHR changes.

The use of oxytocin in labour is a significant contributor to tachysystole. Injudicious use of oxytocin and the failure to recognize and respond to abnormal uterine contraction patterns is a serious cause of impaired fetal oxygenation leading, potentially, to metabolic acidosis and neurologic injury. An abnormal uterine contraction pattern is additional clinical data that helps time fetal neurologic injury. Slow progress of dilatation and descent in a labour induced or augmented by oxytocin is a potential problem. Poor progress may prompt an increase in oxytocin infusion even where the desired uterine contraction pattern has been achieved with a view to promoting better progress. Where uterine contractions are occurring with the desired frequency and duration, the obstetric team must consider other causes for the inadequate progress, often mechanical. In this setting, there is no clinical justification for increasing oxytocin infusion.

While excessive uterine activity can lead to fetal acidosis, there is also literature to suggest that excessive uterine activity can lead to neonatal neurologic injury without a systemic fetal metabolic acidosis. This is thought to be due to the effect of mechanical forces on cerebral perfusion.

The presence of abnormal uterine activity in labour is another variable that may point to intrapartum asphyxia as a cause of neonatal neurologic injury. There is a

---

125 Ibid at p. 34.e4.
body of medical literature that has come to recognize the importance of injudicious use of oxytocin in causing harm.128

A complete intrapartum evaluation of EFM requires consideration of the following:

1. Uterine contractions;
2. Baseline fetal heart rate;
3. Baseline fetal heart rate variability;
4. Presence of accelerations;
5. Periodic or episodic decelerations; and
6. Changes or trends of FHR patterns over time.129

With regard to uterine contractions, the focus tends to be on the absence or presence of tachysystole, but there are other uterine contraction patterns suggestive of a dysfunctional labour.130 Perhaps the variable affecting evaluation of EFM patterns that receives the least attention is item 6 – changes or trends of FHR patterns over time. More attention needs to be paid to this variable when evaluating intrapartum fetal wellbeing. Crucially, the fetal heart rate tracing needs to be interpreted over time and in the context of all the available clinical evidence.131

IX. SENTINEL EVENTS

There has been another dramatic shift from the old green book to the new on the matter of sentinel events. A sentinel event is an acute development that happens quickly and can be quickly fatal to the fetus. This would include a ruptured uterus, a placental abruption and a cord prolapse, as examples. Importantly, a sentinel event should be distinguished from events that occur over time and more gradually, commonly a prolonged partial hypoxia. The old green book failed to explicitly make this important distinction. The new green book seems less concerned.132 With regard to the important issue of causation in these cases, sentinel events do not really present controversy because it is well-accepted that they can be associated with severe morbidity or mortality and the causal connection is clinically not a difficult one to make.

130 For example, coupling or tripling of contractions.
131 Supra note 129 at p. 663.
It is also accepted that sentinel events occurring intrapartum are not necessarily associated with a severe metabolic acidosis revealed in umbilical cord blood gas analysis.\textsuperscript{133}

The patterns of brain injury associated with sentinel events tend to be to the deeper grey matter of the brain. These are described in an article by Rutherford et al.\textsuperscript{134}

**X. APGAR SCORING**

Apgar scoring, developed in 1952, is used to evaluate newborn status in the minutes following birth. This assessment system looks at heart rate, respiratory effort, reflex irritability, muscle tone and colour. A score of 0, 1 or 2 is assigned to each, for a best total score of 10. The value of Apgar scoring in predicting poor long-term outcomes has been the subject of much debate, though it is important to note that Apgar scoring was never intended to measure perinatal asphyxia, but rather assess the need for resuscitation of the neonate.\textsuperscript{135}

To some degree the scoring is subjective\textsuperscript{136}, bringing into question its value in the attempt to solve the causation issue. Apgar scores were a prominent feature of the old green book, and receive less attention in the new green book. The data clearly indicates that babies with low Apgar scores are more likely to have evidence of a metabolic acidosis and are at higher risk of poor neurologic outcome.

It is important to point out that, in the causation analysis, there are far more important indicators of potential fetal asphyxia than the Apgar score. For example, umbilical artery blood gas analysis is a far better tool for identifying the fetus suffering from a metabolic acidosis. In terms of all the variables one must look at to determine the cause for neonatal neurologic injury, Apgar scores should be of relatively low priority when compared to the other factors reviewed in this paper. Put another way, neuroimaging and cord gases will always trump anomalous Apgar scores.

**XI. CEREBRAL PALSY AND NON-MOTOR DISABILITIES**

Many interpreted the old green book as stating that CP was an “essential” criterion in order to connect newborn neurologic injury to intrapartum events. Quite frankly, the old publication was confusing on this point. Certainly the literature cited in the old green book did not support this proposition. This fact has been made even more

\textsuperscript{133} Supra note 4 at p. 97.


\textsuperscript{136} Supra note 4 at p. 116.
explicit in literature published after the old green book, some of it cited here. Despite this, there was considerable reliance on this criteria by many practitioners and authors with, I suggest, some unfortunate results. The reluctance of ACOG to correct this travesty is reflected in the comments on page 15 of the new green book:

...data from clinic-based samples of infants with signs of encephalopathy and referred for MRI indicate that acute brain injury is predominantly associated with “asphyxia”, there are no apparent contributing antenatal risk factors, and developmental outcomes may include neurodevelopmental abnormalities in the absence of cerebral palsy. The apparent disparity between these two bodies of data has led some researchers to suggest that the conclusions in the first publication may need to be modified to accommodate these new data. (Emphasis added)

This unduly cumbersome passage from the new green book, it appears, is a concession that CP is not “essential” to connect newborn neurologic injury to acute intrapartum events. As stated early, no literature has ever supported this now abandoned criterion. It should never have found its way into the old green book. The most that can be said about quadriplegic or dyskinetic CP is that it is the type of CP most closely associated with intrapartum asphyxia. These conditions are by no means the only adverse outcomes that can be caused by intrapartum asphyxia.

The new green book considers the terms “neonatal encephalopathy” and “cerebral palsy” central to the guideline. The term neonatal encephalopathy representing a broad term that includes HIE as a subset, and the term cerebral palsy as too narrow a focus, as that condition is not the only adverse neurological outcome of concern.

Some observers interpreted the essential criteria in the old green book as requiring that a child suffer from CP of a particular type in order to make a causal connection between intrapartum events and brain injury. In my earlier paper I argued that the interpretation was not supported by the underlying data cited in the old green book. Reliable medical literature since the old green book was published in 2003 has confirmed my views. In a 2007 article by Rennie et al it is stated:

Most neonatologists and paediatric neurologists no longer believe that the adverse outcome of intrapartum hypoxic ischemia at term is confined to the motor system, or that the damage cannot affect cognitive function without very significant involvement of the motor pathways.

137 Supra note 4 at p. 1.
138 Supra note 52 at p. 399.
The new green book takes numerous opportunities to point out that most cases of CP are due to factors other than intrapartum events. First, the focus should not only be on CP, but on other non-motor neurologic outcomes as well. It appears that ACOG is reluctantly prepared to concede this medical fact in a round-about way. Second, while the statement may be true, CP and non-motor disability from intrapartum events remain an important problem.

It is also asserted in the new green book that the pathway from intrapartum asphyxia “to subsequent cerebral palsy must certainly progress through neonatal encephalopathy”. Some observations about this statement are in order. First, as pointed out elsewhere, CP is not the only adverse neurologic outcome associated with intrapartum asphyxia. Second, it follows that HIE must be considered in the differential diagnosis for newborns with NE.

Recent data on MRI scanning has shown that parasagittal injury was the most common type of injury in neonatal encephalopathy. As parasagittal injury is related to acute hypoxia-ischemia and often associated with poor outcome, the data demonstrates a far more prominent role for peripartum hypoxia-ischemia in the cause of newborn neurologic injury, and therefore morbidity that includes CP.

As noted earlier, the words “cerebral palsy” have been removed from the new title. This is tacit recognition of the error of the previous edition, explained as new insights obtained in the last decade, that cerebral palsy is not the only neurologic outcome and that developmental problems without motor involvement can be caused by intrapartum hypoxia-ischemia.

Subsequent motor deficits may be predicted in those cases involving severe basal ganglia/thalamic injury. Those neonates with watershed injury involving the white matter and cerebral cortex may have subsequent deficits involving cognitive functioning without motor dysfunction. Clearly, CP is not required in order to attribute neurologic injury and consequent deficits to HIE.

About 50% of CP cases have been attributed to term infants in low-risk pregnancies. At the same time, data suggests that only 8% to 10% of these cases are related to birth asphyxia, asserting that the remainder are due to “poorly

139 Supra note 4 at p. 72.
140 Supra note 4. In particular, see conclusions on p. 15.
141 Ibid. at p. 12.
142 Supra note 52 at p. 402 and Supra note 40 at p. 60.
143 Supra note 4 at p. xviii.
144 Ibid. xviii
145 Supra note 16 at p. 161.
146 Ibid.
understood remote antenatal processes”.\textsuperscript{148} A Case Review by Redline (2008) cites the old green book essential criteria formerly required to make the causal connection. Given that the shortcomings of those old criteria have finally been acknowledged, one ought to be skeptical about the assertion that most cases of CP have poorly understood causes. The Redline case review suggests comorbidity may explain some incidents of CP, with “relatively minor intrapartum insults” being superimposed on placental lesions.\textsuperscript{149} In other words, the fetus may be more vulnerable to intrapartum insults by virtue of antenatal complications.

There is a correlation between NE and developmental delays that do not involve motor dysfunction.\textsuperscript{150} It appears that there is also a correlation between NE and autism.\textsuperscript{151} Yet the new green book appears reluctant to accept that non-motor disabilities may be attributed to NE and HIE.\textsuperscript{152} As I pointed out in my original paper, I suspect there is no more room for debate on this issue. The literature supports a connection between HIE and non-motor disabilities. It was never the case, as the old green book would have us believe, that the presence of CP was essential if a causal connection was to be made between neurologic injury and intrapartum events. At the same time, the new green book does concede the point in places.\textsuperscript{153} To repeat, the report states:

...data from clinic-based samples of infants with signs of encephalopathy and referred to MRI indicated that acute brain injury is predominantly associated with “asphyxia”, there are no apparent contributing antenatal risk factors, and developmental outcomes may include neurodevelopmental abnormalities in the absence of cerebral palsy. The apparent disparity between these two bodies of data has led some researchers to suggest that the conclusions in the first publication of this report may need to be modified to accommodate these new data.\textsuperscript{154}

There is no “may” about it. Intrapartum asphyxia can cause neurodevelopmental disorders that are not CP. The basis for concluding CP was essential in the first publication was not supported by the literature cited in that report. The “new data” described has been available for many years and the new green book, recanting parts of the old one, is long overdue.

In 2006 Gonzalez and Miller published an article showing that children surviving overt neonatal encephalopathy can go on to suffer cognitive impairments in the

\textsuperscript{148} Ibid.
\textsuperscript{149} Ibid.
\textsuperscript{150} Supra note 4 at p. 13.
\textsuperscript{151} Supra note 4 at p. 13.
\textsuperscript{152} Supra note 4 at p. 14. Claims there is an ongoing debate about whether developmental difficulties in the absence of CP arise from NE and HIE.
\textsuperscript{153} Supra note 4 at p. 15.
\textsuperscript{154} Supra note 4 at p. 15.
absence of functional motor deficits, demonstrating quite clearly that CP has never been an essential causation criterion.\textsuperscript{155}

Where a child suffers CP there is a subtype of CP that is strongly associated with acute perinatal hypoxia-ischemia – dyskinetic CP or athetoid CP.\textsuperscript{156} Spastic tetraplegia is also due to prolonged partial intrapartum hypoxia ischemia.\textsuperscript{157} In all cases where intrapartum events are implicated in a poor outcome, one must still keep in mind the possibility that other antenatal or neonatal factors could have played a role in making the particular fetus more vulnerable to hypoxic insults that an otherwise more resilient fetus.\textsuperscript{158} That other comorbid factors are at play does not necessarily diminish the strength of the provable causal connection between intrapartum events and poor outcome. In other words, if intrapartum management was substandard and was a but-for cause of the bad outcome, the antenatal vulnerability would not affect the liability of the intrapartum care-providers.

Hemiplegia (involving one side of the body) is not generally associated with perinatal hypoxia-ischemia and is more likely caused by focal cerebral infarction, or stroke.\textsuperscript{159} It should also be noted that stroke is a risk faced in deliveries complicated by a protracted labour and malposition of the fetal head.\textsuperscript{160} In these circumstances one must look at whether the risk of stroke was due to the failure to properly manage labour complicated by slow progress or an arrest of labour.

Spastic diplegic CP involves spasticity in the lower limbs. It is generally thought to be due to periventricular leukomalacia (PVL), which is the classic response of the preterm fetal brain to hypoxia-ischemia or infection.\textsuperscript{161} While PVL is not usually seen in the term fetal brain, there may be exceptions and where clinical evidence strongly supports perinatal hypoxia-ischemia it may well be causative of PVL.\textsuperscript{162}

\textbf{XII. MULTI-ORGAN INVOLVEMENT}

The 2\textsuperscript{nd} edition notes that multisystem organ\textsuperscript{163} involvement increases the risk of HIE, but the severity of brain injury does not always correlate with the extent of organ involvement.\textsuperscript{164} The point being made in the report is that severe brain damage does not necessarily correspond to severe organ damage. The report fails

\footnotesize
\begin{itemize}
\item \textsuperscript{155} Supra note 32 at p. F454.
\item \textsuperscript{156} Supra note 52 at p. 399.
\item \textsuperscript{157} Ibid at p. 402.
\item \textsuperscript{158} Ibid. at p. 402.
\item \textsuperscript{159} Ibid. at p. 403.
\item \textsuperscript{160} Ibid. at p. 403.
\item \textsuperscript{161} Ibid. at p. 403.
\item \textsuperscript{162} Ibid. at p. 403.
\item \textsuperscript{163} Renal, hepatic, hematologic, cardiac, metabolic derangements and gastrointestinal injury, see Supra note 2 at p. 209.
\item \textsuperscript{164} Ibid. at p. 209
\end{itemize}
to address the scenario where HIE is present in the setting of minimal or no multi-organ involvement or where the multi-organ involvement is transient.

The new green book asserts that in the absence of multiple organ system injury it is doubtful that intrapartum asphyxia was sufficient to cause NE. Caution should be taken in accepting this proposition. In the setting of neuroimaging suggestive of intrapartum injury and a supportive fetal acidosis, the likelihood is that NE is due to an intrapartum cause.

The new green book states:

...fetal hypoxic-ischemic brain injury secondary to acute intrapartum events may not be associated with other multi-organ system injury.

If one presumes a fetus entering labour has a normal acid base status, then umbilical cord blood demonstrating a metabolic acidosis means that the labour was associated with impaired oxygenation leading to the metabolic acidosis which, in all cases, will be reflected in the fetal heart tracing. The lack of multi-organ involvement does not diminish this fact. Coupled with neuroimaging showing a topography of injury associated with injury at or near the time of birth leads to the inevitable conclusion that the neurologic injury is acute in timing. There is a clear correlation between NE at the time of delivery and metabolic acidosis.

XIII. MECONIUM

The presence of meconium in the amniotic fluid is a potential indicator of fetal stress and must be considered in the context of the entire clinical picture. Meconium aspiration is certainly a risk for morbidity, but there is usually more going on clinically than just the presence of meconium.

Meconium is more likely to be an issue in a post-term pregnancy which is one that continues beyond 42 weeks. These pregnancies expose the fetus to increased risk of morbidity and mortality. Of particular concern is the increased risk of Meconium Aspiration Syndrome (MAS) in post-term pregnancies.

---

165 Ibid. at Ch. 6, p. 96. Note in particular the study at footnote 103 of the new green book.
166 Ibid. at p. 98. See the two studies relied on at footnotes 116 and 118.
167 Ibid. at Ch. 6, p. 96.
168 Ibid at Ch. 5, p. 80.
170 Ibid. at p. 521.
XIV. THE 30-MINUTE RULE

The new green book cites much controversy over the so-called “rule” that hospitals ought to be able to begin a cesarean delivery within 30 minutes of the decision to proceed. The report concludes “even in the presence of significant acidemia, most newborns will be neurologically normal”.\(^{171}\) I consider that comment a *non sequitur*. The fact that most newborns can tolerate severe acidemia does not mean that they should be unnecessarily exposed to severe acidemia and the risk of permanent neurologic injury or death. Surely the clinical circumstances ought to dictate the speed with which one proceeds to cesarean delivery. One hopes that the reader will not make the dreadful mistake of interpreting this conclusion as justifying complacency in the presence of evidence of impaired fetal oxygenation.

In circumstances where the intrapartum clinical circumstances are pointing to a potentially unfriendly intrauterine environment, a fetus having difficulty coping with the stress of labour, and/or where the prospects of a safe vaginal delivery seem unlikely, 30 minutes may simply be much too long. In my view, ACOG should not be reinforcing the notion that one can wait 30 minutes where the clinical scenario, by any reasonable measures, suggests otherwise. The fact that some babies, or even most babies, avoid neurologic injury after 30 minutes does not justify putting them in peril.

It seems that the new green book is only prepared to concede the need for cesarean section in the shortest possible time in the setting of a sentinel event like a cord prolapse, uterine rupture or placental abruption, particularly when accompanied by a fetal bradycardia.\(^{172}\) Surely this too sends the wrong message to obstetrical care providers. It is not only sentinel events that can result in CP (and other non-motor neurologic injury), but prolonged partial asphyxia that results in a severe metabolic acidosis. Thus, the rarity of CP is in no way a justification for not expediting the rescue of babies apparently having difficulty coping with labour stress, no matter the reason. By the way, even in the case of a sentinel event, presumably one need not see a fetal bradycardia to know that delivery as soon as possible is needed. It is inconceivable to me that the presence of bradycardia is required for one to know to expedite delivery. The obstetrical team must anticipate the potential morbidity, not wait for it to occur.

In offering its conclusions on the 30-minute rule, ACOG offers this exceedingly unhelpful conclusion:

> Exceeding the 30 minutes from decision to incision in many clinical circumstances, which were categorized as an emergency cesarean delivery, may not represent substandard care.\(^{173}\)

\(^{171}\) Supra note 4 at Ch. 6, p. 102.
\(^{172}\) Ibid. at Ch. 6, p. 104.
\(^{173}\) Ibid. at Ch. 6, p. 105.
First, the corollary may be that in some cases exceeding 30 minutes is substandard. More crucially, some clinical scenarios require intervention much quicker than 30 minutes. Where the clinical indicators suggest that the intrauterine environment is not a friendly one for the fetus the obstetric team needs to be ready to act. ACOG appears to have no hesitation in setting the standard of care bar quite low without adequately factoring in of all the data needed to make sound obstetrical care management decisions.

**XV. DIFFERENTIAL DIAGNOSIS**

The causation analysis must employ the differential diagnosis model. A list of possible causes for neonatal neurologic injury must be made and then the most likely cause determined based on all the available relevant data. Where non-hypoxic-ischemic causes such as infection, trauma, inborn errors of metabolism or other genetic disorders have been ruled out, it follows that intrapartum causes are most likely. Where these alternative diagnoses have been eliminated, the studies have shown that the neuroimaging data is consistently compatible with acute hypoxic-ischemic injury in most based of newborn NE.

The new green book cites evidence to support a strong relationship between low birth weight and NE and CP. This relationship, however, does not rule out intrapartum events as possible contributing and even causative factors. The fetus showing growth abnormalities in the third trimester will undoubtedly be more vulnerable to intrapartum stresses, a factor that obstetrical care providers must keep in mind when making intrapartum care management decisions.

In applying the differential diagnosis, the absence of some clinical evidence is not an insurmountable obstacle to identifying the most likely cause for newborn neurologic injury. One must do the best by evaluating all the available clinical data at hand. The differential diagnosis should be applied to all the available evidence in determining, on a balance of probabilities, the diagnosis that best explains the outcome. This should be so from both a legal perspective and a medical perspective.

**XVI. CONCLUSIONS**

Chapter 13 of the new green book purports to provide a “comprehensive multidimensional assessment tool to determine the likelihood that an acute hypoxic-ischemic event that occurred within close temporal proximity to labor and delivery was the cause of NE and CP. The differential diagnosis approach should be used in determining the most likely cause for NE. The new green book cites evidence to support a strong relationship between low birth weight and NE and CP. However, this relationship does not rule out intrapartum events as possible contributing and even causative factors. The fetus showing growth abnormalities in the third trimester will undoubtedly be more vulnerable to intrapartum stresses, a factor that obstetrical care providers must keep in mind when making intrapartum care management decisions.

In applying the differential diagnosis, the absence of some clinical evidence is not an insurmountable obstacle to identifying the most likely cause for newborn neurologic injury. One must do the best by evaluating all the available clinical data at hand. The differential diagnosis should be applied to all the available evidence in determining, on a balance of probabilities, the diagnosis that best explains the outcome. This should be so from both a legal perspective and a medical perspective.

---

175 Ibid.
176 Supra note 4 at Ch. 5, p. 72.
delivery contributed to neonatal encephalopathy”. It is entirely deficient in this respect. The important observations, most attracting criticism, from chapter 13 are:

i. MRI done early in the neonatal period can identify the window of time of injury, but not definitively specify the cause;\(^\text{177}\)

ii. Despite the three-tier FHR interpretation system, EFM remains unreliable in identifying clinical markers strongly predictive of long-term outcome;\(^\text{178}\)

iii. “In the first edition of this guideline, the task force outlined criteria deemed essential to establish a causal link between intrapartum hypoxic events and CP. For the current edition, the task force determined that a broader perspective may be more fruitful”\(^\text{179}\)

iv. “If a comprehensive etiologic evaluation is not possible, the term HIE should best be replaced by neonatal encephalopathy because neither hypoxia nor ischemia can be assumed to have been the unique initiating mechanism”.\(^\text{180}\)

v. To determine the likelihood that an acute hypoxic-ischemic event occurring close to the time of delivery contributed to NE, there must be a comprehensive multidimensional assessment of all potential contributing factors including:

   a. Maternal medical history;
   b. Obstetric antecedents;
   c. Intrapartum factors (including fetal heart rate monitoring results and issues relating to the delivery itself); and
   d. Placental pathology;\(^\text{181}\)

vi. The causation assessment involves:

   a. Establishing an actual NE;
   b. Identifying other signs consistent with an acute event including:
      i. Low Apgar score
      ii. Fetal umbilical artery acidemia;
      iii. Neuroimaging evidencing acute brain injury;

\(^{177}\) Ibid. at Ch. 13, p. 206.
\(^{178}\) Ibid.
\(^{179}\) Ibid. at Ch. 13 p. 207.
\(^{180}\) Ibid. at Ch. 13 p. 207.
\(^{181}\) Ibid. at Ch. 12, p. 208.
iv. Multi-organ failure;
c. Type and timing of factors that can cause acute injury:
   i. Sentinel events;
   ii. FHR patterns consistent with acute intrapartum event
   iii. Neuroimaging patterns consistent with an acute intrapartum event;
d. The absence of more remote contributing factors;
e. Development of spastic quadriplegia or dyskinetic cerebral palsy (Other developmental abnormalities may occur, but they are not specific to acute intrapartum hypoxic-ischemic encephalopathy).\textsuperscript{182}

Despite the recognition of deficiencies in the old green book, the new report has failed to provide clear guidance on causation. This new edition obscures the issues at many stages of the report. For example, the report in many places continues to view cerebral palsy as the likely outcome from acute intrapartum asphyxia.\textsuperscript{183}

With regard to item i, neuroimaging can indeed define the window of opportunity for injury. The importance of this fact means that the injury occurred within 48 or so of birth and to attribute injury to a cause other than intrapartum hypoxia-ischemia means finding another event during that relatively small window of opportunity that might explain the outcome. Where the neuroimaging supports an acute cause, the FHR tracing has evidence of impaired oxygenation and the umbilical cord gases demonstrate a metabolic acidosis compatible with acute brain injury, the case for acute injury has been made out.

With regard to item ii, the three-tier system for FHR pattern interpretation has little bearing on this discussion. The only point worth emphasizing is that a labour dominated entirely by category I tracings means a well-oxygenated fetus in the intrapartum period. Both category II and category III tracings can be compatible with intrapartum injury. Again, where the neuroimaging and cord gases match up to acute injury, the tracing will too.

Item iii appears to reluctantly acknowledge the mistakes in the 1\textsuperscript{st} edition of the green book, but the task force is not very contrite. The conclusions offered in chapter 13 of the new edition are too vague and defensive to be of any real use in the clinical setting. There still remains the focus on CP in item vi.e., despite the acknowledgement that non-motor neurodevelopmental problems can be caused by intrapartum asphyxia.

In terms of the differential diagnosis, item iv suggests that HIE cannot be established without a comprehensive etiologic assessment. Comprehensive clinical data is not always available in every case, but that should not prevent landing on the most

\textsuperscript{182} Ibid. at Ch. 13, p. 211.
\textsuperscript{183} Ibid. at p. 2.
likely diagnosis. Within the limitations of the available clinical data, one is still able to rule out some diagnoses and attribute cause to that diagnosis that seems most likely based on the information at hand.

Item v fails to acknowledge that the listed factors are not required to prove causation. Even under the old guidelines these factors were not essential but only “suggestive”.

The balance of the factors are dealt with elsewhere in this paper.

Another problem with the 1st edition, that is perpetuated in the second, is the constant attribution of neurologic injury to any cause but intrapartum asphyxia, when the guidelines should be attempting to better articulate factors pointing to or away from intrapartum events. Undoubtedly the reports acknowledge birth asphyxia as a cause of NE, but not in a way that recognizes the overall importance of intrapartum asphyxia to neurologic injury. The reports go out of their way to emphasize that the indicia of HIE are more commonly associated with other conditions.184

Precise intrapartum assessment of the fetus for the purposes of guiding management of labour cannot be achieved. First, there is no method to accurately measure the precise effect that intermittent hypoxia is having on fetal well-being. Second, during labour and delivery, it is not possible to know whether the fetus is suffering ischemic insult that might lead to neurologic injury.

Some form of causation algorithm would be useful. I do not purport, at this point, to design such an algorithm, but I will set out the steps a lawyer should take in the causal analysis to determine if a potential case has merit. They are as follows:

i. The first step is to look at the neuroimaging:
   a. Is there imaging (likely an initial cranial ultrasound) done in the first 48 hours of life?
   b. Does the imaging show cerebral edema (consistent with recent injury)?
   c. Does the imaging show an absence of remote structural brain damage (pointing away from an antenatal cause)?
   d. Is there imaging at 72 hours of age or later showing a resolving cerebral edema?
   e. Does the imaging at 5 to 7 days show the patterns of injury associated with either a prolonged partial asphyxia or a profound total or near-total asphyxia?
   f. Overall, does the available imaging point to neurologic injury within hours to a couple of days prior to delivery?

184 Ibid. at p. 3.
ii. Is there analysis of umbilical cord blood?
   a. Is there both a venous and arterial sample?
   b. Where there is a difference between the values in the venous and arterial samples, is the arterial sample more acidic?
   c. Is there evidence of a severe metabolic acidosis?
   d. If there is not evidence of a severe metabolic acidosis, is there a reason (i.e., in utero resuscitation, sentinel event, tainted sample)?

iii. Is there intrapartum evidence of a problem with the FHR, particularly in relation to uterine contractions?
   a. Was oxytocin used to induce or augment the labour?
   b. What was the uterine contraction pattern during active labour (frequency and duration)?
   c. How did the FHR pattern respond to the uterine activity?
   d. Was there a tachysystole or other abnormal uterine response?
   e. Were there FHR heart rate patterns indicative of potential impairment of fetal oxygenation?
   f. How did the FHR patterns and uterine activity respond to resuscitative measures?
   g. Was there evidence of distress, such as the presence of meconium?
   h. Does the FHR pattern demonstrate fetal decompensation?

iv. Where there any birth complications that affected fetal well-being?
   a. Cord prolapse, uterine rupture, placental abruption, shoulder dystocia, poor progress, macrosomia, infection, etc.

v. What was the condition of the baby at birth?
   a. Was there evidence of NE?
   b. Was the baby in need of resuscitation?
   c. Was there evidence of organ dysfunction other than the brain?

vi. Was there any antenatal evidence that might affect fetal health?
   a. Growth restriction, maternal hypertension, gestational diabetes, oligohydramnios, etc.?
   b. Decreased fetal movement?

vii. Was there any evidence of placental dysfunction?

viii. Does the baby have any genetic or metabolic disorders that might explain the outcome?

ix. Are there any neonatal developments to explain the outcome?
   a. Hypoglycemia?
   b. Hyperbilirubinemia?
x. Did the baby develop seizures?

xi. Did the baby show multi-organ dysfunction?

Authors like Karin Nelson must be favoured by ACOG and those advocating the ACOG approach to causation of neonatal neurologic injury. Arguably both sides of the divide are pushing their position too vigorously. A quote from an article by Nelson states:

The literature on the etiology of CP is impressive in its perseverative preoccupation with birth asphyxia despite evidence that this is a minor part of the whole picture, and despite the failure of interventions based on the birth asphyxia hypothesis to lead to effective prevention strategies.¹⁸⁵

My view is that Nelson’s perspective is at least, in not more, a function of perseverative preoccupation. Her premise is based on two hypotheses of her own which, based on reliable medical literature, are on the shakiest of foundations. First, newborn neurologic injury from acute intrapartum events (both CP and non-motor disability), are not as small as suggested and, even if small in absolute numbers, remain an important and preventable cause of brain injury. It is entirely inappropriate to characterize these events as a “minor” part of the larger picture. It is bigger than she is prepared to acknowledge. Particularly when co-morbid causes are considered. Second, the interventions that Nelson says have failed obviously relate to EFM. Undoubtedly, the conventional wisdom within the practicing obstetrical community is that EFM has very important value in recognizing the fetus having difficulty coping with the stress of labour. There are good reasons why even those who adhere to the Nelson school of thought, like ACOG, promote continuous EFM in higher risk situations or when labour is augmented or induced with oxytocin. It is clearly an accepted fact that certain periodic changes in the fetal heart rate are compatible with hypoxia and must dictate the ongoing management of intrapartum care when encountered, including the possibility of intervention to expedite delivery.

One cannot look at all forms of CP in aggregate to draw conclusions about either the prevalence of CP from acute peripartum events or about the efficacy of monitoring with EFM. More recent data establishes that about 80% of cases of dyskinetic CP are caused by hypoxia-ischemia at term, which subtype represents between 7% and 15% of all CP.¹⁸⁶

¹⁸⁵ Supra note 20 at p. 760.
¹⁸⁶ Supra note 52 at p. 399.
Otherwise strong evidence for neurologic injury from acute intrapartum events should not be trumped because one causal variable, such as cord gases or multi-organ dysfunction, is not present.\textsuperscript{187}

The new green book is certainly less of an obstacle to reliably proving causation in birth injury cases than its predecessor. Despite its stated objective, it is not a useful guide. Acknowledging the importance of intrapartum events as a contributor to newborn neurologic injury is surely a vital step in reducing morbidity. The fact that obstetrical care providers might be held accountable for bad outcomes resulting from substandard care, which arguably also contributes to better patient safety, should not influence or taint the causal analysis. Understanding causation will inform obstetrical care, but in the end the matter of causation is really one for neonatologists, neurologists and neuroradiologists. I am sure the interest taken by ACOG in the subject is influenced, to some degree, by the desire to improve obstetrical care and reduce adverse outcomes, but my sense is that medical malpractice liability remains a very prominent consideration in the way new green book has delivered the message.

\textsuperscript{187} Ibid. at p. 400.