[ORIGINAL ARTICLE] for JOGR

# Title: Intrapartum risk factors for neonatal encephalopathy leading to cerebral palsy among women without apparent sentinel events

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**Running foot:** Intrapartum risk factors for CP

**Abstract**

**Aims:** To determine intrapartum factors associated with neonatal encephalopathy leading to cerebral palsy (NE-CP).

**Methods:** Analyses of 70 NE-CP cases fulfilling all of the following criteria: cephalic singleton pregnancy attempting vaginal delivery (AVD) at gestational week (GW) ≥ 36, intrapartum occurrence of non-reassuring fetal status without apparent causes following reassuring fetal status on admission, and development of NE-CP, in comparison with 210 AVD controls with infants with 1- and 5-min Apgar scores ≥ 8 matched for GW, maternal parity, and use of uterotonics. Suboptimal care was defined as delayed reaction resulted from misinterpretation of fetal heart rate (FHR) tracing or inappropriate trial of instrumental delivery (TOID). Successful and failed TOID were defined as vaginal and cesarean deliveries after TOID, respectively. The 210 controls were assumed not to have had suboptimal care.

**Results:** The rates of successful (34% vs. 12%) and failed TOID (11% vs. 0.0%), cesarean section (34% vs. 14%), suboptimal care (57% vs. 0.0%), pregnancy-induced hypertension (11% vs. 2.4%), birth weight ≥ 3800 g (8.6% vs. 1.9%), subgaleal hemorrhage (16% vs. 0.0%) were significantly higher in cases than controls. Selection with the stepwise method and logistic regression analysis identified four independent risk factors for NE-CP: suboptimal intrapartum care (odds ratio [95% confidence interval], 2.21 [1.99 – 2.47]), cesarean section (1.19 [1.08 – 1.31]), successful TOID (1.14 [1.03 – 1.25]), and hypertension (1.20 [1.01 – 1.42]).

**Conclusions:** Training programs for improved interpretation of FHR tracing and appropriate TOID are required to prevent NE-CP among healthy and mature fetuses in Japan.

(Word count <250)

**Key words:** fetal heart rate tracing, instrumental delivery, macrosomia, non-reassuring fetal status, shoulder dystocia, vacuum delivery

## Introduction

Healthy fetuses based on fetal hear rate (FHR) tracing at the onset of labor pains can develop neonatal encephalopathy (NE) and subsequently develop cerebral palsy (CP). Well-known causative factors for CP derived from hypoxic conditions include placental abruption, uterine rupture, cord prolapse, fetomaternal hemorrhage, or placenta previa [1 - 5]. However, some infants develop NE leading to CP (NE-CP) in the absence of such risk factors.

As suboptimal intrapartum care is commonly seen with NE, especially in neonates with metabolic acidemia in Sweden [6], and as NE proceeds to CP in some cases [7], suboptimal intrapartum care may be a risk factor for NE-CP. Instrumental deliveries, including vacuum and forceps deliveries, are widely used in patients requiring facilitated delivery. However, as some trials of instrumental deliveries (TOID) fail to provide successful vaginal delivery, some cases of failed TOID require cesarean section during labor. In such cases with failed TOID for non-reassuring fetal status (NRFS), delay in delivery increases the theoretical risk of NE-CP. Vacuum delivery is associated with serious complications, such as subgaleal hemorrhage (SGH), and some of neonates with SGH die or develop CP later [8, 9]. Thus, TOID may be associated with increased risk of NE-CP. However, as the prevalence of CP is low, approximately 1 per 1000 live births for infants weighing $\geq$ 2.5 kg [10, 11], and as intrapartum hypoxia accounts for less than 30% of all cases of NE [12, 13], it is unclear whether suboptimal intrapartum care and TOID increase the risk of NE-CP.

The present study was conducted to determine the intrapartum factors associated with increased risk of NE-CP.

## Materials and Methods

This study was conducted after approval by the Ethics Committee of Hokkaido University Hospital.

*Selection of 70 cases with NE-CP*

The Japan Council for Quality Health Care (JCQHC) launched a new medical insurance system, the Japan Obstetric Compensation System for Cerebral Palsy, on January 1, 2009, to compensate for cerebral palsy (CP) derived in principle from intrapartum hypoxia and to improve perinatal care. The details of this system were described previously [4]. In this system, maternal and neonatal records were audited by members of the investigation committee belonging to the JCQHC. One of the authors (HM) was a member of this committee. Each case was clinically assessed for the presence or absence of suboptimal ante- and intrapartum care, which was assigned by consensus. Researchers can gain access to a detailed report made by the committee after approval by the JCQHC. We were provided access by the JCQHC to 244 detailed reports made up to March 31, 2013, in which detailed clinical courses of 244 infants born to 244 women, causative factors for NE-CP determined by the investigation committee, and the presence or absence of suboptimal care were recorded. However, personal information regarding the date of birth, including year and month, place of birth, maternal age, and maternal body height and weight, were masked for privacy protection. All of the 244 infants were born in or after January 2009.

We reviewed all 244 reports for the 244 cases, focusing on clinical courses, FHR tracing, causative factors for CP, and the presence or absence of misinterpretation of FHR

tracing, inappropriate TOID, and neonatal SGH. We identified 70 and 174 cases that did and did not fulfill all of the following four conditions: (1) cephalic singleton pregnancy attempting vaginal delivery (AVD) on or after gestational week (GW) 36, (2) reassuring fetal status at the onset of labor pains based on FHR tracing, (3) intrapartum occurrence of NRFS on FHR tracing in the absence of placental abruption, uterine rupture, cord prolapse, fetomaternal hemorrhage, or placenta previa/low lying placenta, and (4) diagnoses of NE at birth and subsequently CP by neuropediatricians. Thus, all 70 cases were judged to be NE-CP associated with intrapartum factors other than placental abruption, uterine rupture, cord prolapse, fetomaternal hemorrhage, or placenta previa/low lying placenta. The 70 neonates exhibited a pH of 6.86±0.78 with base deficit of 20.1±6.9 mmol/L in the umbilical cord blood or neonatal blood at birth or on admission to neonatal intensive care unit. In these 70 neonates, Apgar score at 1-min was < 3 in 50 (71%), < 5 in 64 (91%), and < 7 in 68 (97%) neonates, and that at 5-min was < 3 in 24 (34%), < 5 in 47 (67%), and < 7 in 64 (91%) neonates. Neither congenital malformation, inborn error of metabolism, nor infection was detected in the 70 infants.

*Selection of 210 controls*

We used a database provided by the Japan Society of Obstetrics and Gynecology (JSOG) [14] that included information on 11724 mothers who were registered at the JSOG Successive Pregnancy Birth Registry System and gave birth during the period from November 1, 2009, to December 31, 2009. From this database, we abstracted 2809 mothers who fulfilled all three of the following conditions: (1) AVD with cephalic presentation on and after GW ≥ 36, (2) no occurrence of placental abruption, uterine rupture, cord prolapse, fetomaternal hemorrhage, or placenta previa/low lying placenta, and (3) neonate with both 1- and 5-min Apgar scores of ≥ 8. Three controls for each case (3:1) were chosen after matching for GW at delivery, maternal parity (nulliparous

or not), and use of uterotonics. Thus, a total of 210 mother–child pairs were chosen from the database of the JSOG Successive Pregnancy Birth Registry System for controls. In these 210 neonates, neither congenital malformation, inborn error of metabolism, SGH, nor infection was detected during a several-day stay at the obstetrical facilities. Data on the umbilical cord blood pH were not available for these control infants.

*Definitions and predefined assumption in this study*

Suboptimal intrapartum care was defined as delayed reaction to NRFS due to misinterpretation of FHR tracing and or inappropriate TOID not fulfilling two prerequisite conditions, i.e., "fetal head engagement" and "full dilatation of the uterine cervix." The delayed reaction to NRFS due to misinterpretation of FHR tracing was defined as follows: the investigation committee belonging to the JCQHC pointed out that an early delivery had not been attempted in the presence of NRFS based on FHR pattern of level $\geq 4$ (according to the Japanese guidelines [14]) lasting for a considerable time and/or FHR pattern of level 5 lasting more than 120 min until delivery. The inappropriate TOID was defined as a follow: the investigation committee concluded that TOID performed before full dilatation of the uterine cervix and/or fetal head engagement worsened fetal condition. As the 210 control infants left obstetric facilities several days after birth according to the clinical path of each facility, all of the 210 controls were assumed not to have developed NE and not to have received suboptimal care. Successful and failed TOID were defined as vaginal and cesarean deliveries after TOID, respectively, irrespective of the condition of the neonate at birth. Emergent cesarean section (ECS) was defined as that performed in women during labor. Hypertensive disorders included preeclampsia and gestational hypertension.
Hypertensive disorders included preeclampsia and gestational hypertension.

*Statistical analyses*

All of the data are presented as the means ± SD or frequency. Fisher's exact test was used for comparison of categorical data. Factors that were significantly correlated with NE-CP were determined by univariate and multivariate logistic regression analyses performed using IBM SPSS Statistics 18.0 software (SPSS Inc., Chicago, IL). We used a stepwise method (Wald) to choose independent risk factors for NE-CP and used logistic regression analysis to determine the odds ratio (OR) with 95% confidence interval (95%CI) of independent risk factors. In all analyses, $P < 0.05$ was taken to indicate statistical significance.

**Results**

The suboptimal intrapartum cares were identified in as many as 40 (57%) of the 70 cases (Table 1). The delayed reaction to NRFS due to misinterpretation of FHR tracing and the inappropriate TOID occurred in 38 and 4 women, respectively. Thus, both the delayed reaction to NRFS and inappropriate TOID occurred in two women. In three of four women with inappropriate TOID, TOID was performed before full dilatation of the uterine cervix and fetal head engagement. Frequency of low Apgar scores of < 3, < 5, and < 7 did not differ significantly between women with and without suboptimal cares (Table 2).

The mean GW at delivery, distribution of GW at delivery, frequencies of nulliparous women, and the rate of uterotonics use did not differ between the 70 cases and 210 controls (Table 3). As control subjects were matched for cases with regard to the use of uterotonics, the rate of uterotonics use in controls in the present study (54%) was higher

than that of approximately 23% in general pregnant Japanese women [15]. Frequencies of TOID, successful and failed TOID, ECS, suboptimal intrapartum care, hypertensive disorders, birth weight ≥ 3800 g, and SGH were significantly higher in the cases than controls. Of the 11 cases with SGH, 10 (91%) experienced TOID, and four of the 10 with TOID and SGH experienced failed TOID. Thus, within the NE-CP cohort, SGH occurred significantly more often in cases with than without TOID (31% [10/32] vs. 2.6% [1/38], respectively, $P = 0.0017$).

In univariate analysis, the OR (95% CI) for 70 cases compared to 210 controls was 5.96 (3.19 – 11.13) for TOID, 3.69 (1.94 – 7.02) for successful TOID, 27.0 (3.31 – 220) for failed TOID, 3.13 (1.67 – 5.86) for ECS, 279 (36.9 – 2103) for suboptimal intrapartum care, 5.29 (1.67 – 16.8) for hypertensive disorders, 2.08 (0.95 – 4.54) for birth weight ≥ 3500 g, 4.83 (1.32 – 17.6) for birth weight ≥ 3800 g, and 39.0 (4.93 – 308) for SGH. All nine of the above factors were candidates as independent risk factors for NE-CP. After selection with the stepwise method, the following four factors were chosen as independent risk factors for NE-CP (Table 4): suboptimal intrapartum care (OR, 2.21; 95%CI, 1.99 – 2.47), hypertensive disorders (1.20; 1.01 – 1.42), ECS (1.19; 1.08 – 1.31), and successful TOID (1.14; 1.03 – 1.25). Thus, among the causative factors other than placental abruption, uterine rupture, cord prolapse, fetomaternal hemorrhage, and placenta previa/low lying placenta, suboptimal intrapartum care was the greatest risk factor for NE-CP in fetuses assumed to be healthy at the commencement of labor.

## Discussion

The present study demonstrated that suboptimal intrapartum care was the greatest risk factor for NE-CP among pregnant Japanese women who attempted vaginal delivery

191 with cephalic presentation of healthy fetuses at GW 36 or later and did not develop
192 placental abruption, uterine rupture, cord prolapse, fetomaternal hemorrhage, or
193 placenta previa/low lying placenta. Other independent risk factors for NE-CP
194 determined in this study included hypertensive disorders, ECS, and successful TOID.

195 Suboptimal intrapartum care, defined as a delayed reaction to NRFS and/or
196 inappropriate TOID not fulfilling prerequisite conditions, was noted in 40 (57%) of the
197 70 cases with NE-CP and increased the risk of NE-CP independently by 2.2-fold
198 compared to women who were not given suboptimal intrapartum care in this study. This
199 was suggested by previous studies in infants without congenital malformation, inborn
200 error of metabolism, or infection [6, 16 - 18]: in a study of 141 term infants with CP
201 born in 1984 – 1987 in the UK, care giver's failure to respond to NRFS occurred more
202 often for CP compared to controls (OR, 4.5; 95%CI, 2.4 – 8.4) [16]; in regional audits
203 of 49 cases with NE born in 1997 in the UK, significant or major episodes of
204 suboptimal care were identified in 64% of NE cases [18]; in regional audits of 52 term
205 infants born with NE in 1997 – 2000 in New Zealand, suboptimal fetal monitoring
206 practice was identified in at least 42% of cases [17]; and in audits of 47 and 22 NE
207 infants with and without metabolic acidemia at birth defined as by umbilical artery pH <
208 7.00 and base deficit ≥ 12 mmol/L born in 2003 – 2010 in Sweden, suboptimal care was
209 identified in 47% (22/47) and 20% (6/30) of cases, respectively [6]. Thus, suboptimal
210 intrapartum care is prevalent worldwide among neonates with NE and is a major
211 intrapartum risk factor for NE and/or NE-CP after excluding well-known risk factors,
212 such as placental abruption, uterine rupture, and cord prolapse.

213 TOID was not an independent risk factor for NE-CP in this study. However, both ECS
214 and successful TOID increased the risk of NE-CP independently by 19% and 14%,
215 respectively. As failed TOID inevitably requires ECS and even successful TOID was an

independent risk factor for NE-CP, the present study suggested that TOID should be considered as an independent risk factor for NE-CP.

Both TOID and ECS are known to be associated with CP in term infants having OR of 1.9 (95% CI, 1.6 - 2.3) and 1.8 (1.6 - 2.0), respectively compared to population with counterpart characteristics [1]. However, it is uncertain whether TOID is a causative factor for NE-CP. ECS is used in women with difficult labor irrespective of the use of TOID, and ECS without TOID accounted for 67% (16/24) of cases and for 100% (30/30) of controls in this study. In a population-based study on the frequencies of subdural and cerebral hemorrhage according to delivery mode by Towner et al. [19] examining 583340 live-born singleton infants born to nulliparous women between 1992 and 1994 and weighing between 2500 and 4000 g in California, OR of subdural or cerebral hemorrhage compared with spontaneous vaginal delivery was 1.4 (0.8 – 2.6) for cesarean section without labor, 2.3 (1.7 – 3.2) for ECS without TOID, 2.7 (1.9 – 3.9) for vaginal delivery with vacuum extraction, 3.4 (1.9 – 5.9) for vaginal delivery with forceps delivery, 7.3 (2.9 – 17.2) for vaginal delivery with combined use of vacuum and forceps, and 8.8 (3.9–19.9) for ECS after TOID [19]. The risk of subdural or cerebral hemorrhage associated with ECS (OR of 0.9 [0.6 – 1.4] compared to vacuum extraction) did not differ from that associated with vaginal delivery after vacuum extraction, suggesting that difficult labor requiring cesarean section or vacuum extraction was causative for subdural or cerebral hemorrhage, although an increased number of operative interventions, including vacuum extraction, use of forceps, and ECS, additively increased the risk of subdural or cerebral hemorrhage [19]. Thus, it was not surprising that both ECS and successful TOID were independent risk factors for NE-CP in this study.

SGH is a rare but potentially lethal medical emergency, and is associated with an

241 increased risk of NE [8, 9, 20, 21] as was confirmed in this study, although not an
242 independent risk factor for NE-CP in this study. Its frequency is estimated to be 4 to 5
243 per 10000 spontaneous deliveries and 40 to 60 per 10000 vacuum-assisted deliveries [8,
244 9]. Ten (91%) of the 11 neonates with both SGH and NE-CP were after TOID in this
245 study. In other studies, the frequency of TOID among neonates with SGH varied from
246 64% (79/123) [8], 77% (32/42) [9], 85% (27/33) [22], and to 97% (36/37) [20]. As the
247 general frequency of TOID was estimated to be less than 20% based on previous studies
248 (instrumental delivery of 7% ± 4% in 2004 in 124 facilities in the USA [23], the vacuum
249 delivery of 10% in 1982-92 in Western Australia [20], the vacuum delivery rate of 14%
250 in 2012 in Sweden [24] as well as 12% in the 210 control women in this study), it was
251 apparent that TOID increased the risk of SGH. Poor outcome is likely to occur in
252 neonates with SGH; of 42 neonates with SGH in Taiwan, 13 (31%) had poor outcomes,
253 including death in five, epilepsy in four, severe auditory dysfunction in three, CP in two,
254 and renal vein thrombosis in one [9]. In another study in Western Australia [20], of 37
255 neonates with SGH, one died and four of 25 with follow-up developed minor
256 neurological disabilities.

257 Hypertensive disorder in pregnancy was also an independent risk factor for NE-CP in
258 this study. There has been controversy regarding whether preeclampsia is associated
259 with increased risk of CP. Mann et al. [25] conducted a population-based study to
260 address this issue, examining 122476 mother–child pairs, including 337 children
261 (0.28%) with CP and 4226 (3.5%) women with preeclampsia. Children born to mothers
262 with preeclampsia were more likely to have CP compared to those of mothers without
263 preeclampsia (OR of 1.94 [1.25 – 2.97]) [25]. These observations suggested that more
264 intensive monitoring is required at term in women with hypertensive disorders, and this
265 is emphasized in the current Japanese guidelines [26].

A major limitation of this study was that control mother–child pairs were assumed not to have had suboptimal intrapartum care. It is possible that suboptimal intrapartum care was given in a very small number of control women, but not leading to NE in the neonate. Therefore, there is the possibility of overestimation in the risk of NE-CP associated with suboptimal intrapartum care in this study.

In conclusion, the present study suggested that, among factors other than well-known factors, including placental abruption, uterine rupture, cord prolapse, fetomaternal hemorrhage, and placenta previa/low lying placenta, suboptimal intrapartum care was the greatest risk factor for NE leading to CP among mature and healthy fetuses on admission to facilities for delivery and confirmed that ECS as well as successful TOID, defined as vaginal delivery after TOID, were significant risk factors for NE leading to CP. Training programs for improved interpretation of FHR tracing and appropriate TOID are required to prevent NE-CP.

**Acknowledgements**

This study was supported by a Grant-in-Aid for Scientific Research from the Ministry of Education, Science, Sports, and Culture of Japan (No. 2646246804).

**Conflict of Interest**

All authors declare that they have no financial relationships with biotechnology manufacturers, pharmaceutical companies, or other commercial entities with an interest in the subject matter or materials discussed in this manuscript.

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290 **References**

291 1. Thorngren-Jerneck K, Herbst A. Perinatal factors associated with cerebral palsy in
292 Children born in Sweden. ObstetGynecol 2006;108:1499–505.

293 2. Nelson KB. Causative factors in cerebral palsy. Clin Obstet Gynecol 2008;51:
294 749–62.

295 3. Gilbert WM, Jacoby BN, Xing G, Danielsen B, Smith LH. Adverse obstetric events
296 are associated with significant risk of cerebral palsy. Am J Obstet Gynecol 2010; 203:
297 328.e1–5.

298 4. Yamada T, Yamada T, Morikawa M, Minakami H. Clinical features of abruptio
299 placentae as a prominent cause of cerebral palsy. Early Hum Dev 2012; 88: 861–864.

300 5. Kadooka M, Kato H, Kato A, Ibara S , Minakami H, Maruyama Y. Effect of neonatal
301 hemoglobin concentration on long-term outcome of infants affected by fetomaternal
302 hemorrhage. Early Hum Dev 2014; 90: 431–434.

303 6. Jonsson M1, Agren J, Norden-Lindberg S, Ohlin A, Hanson U. Suboptimal care and
304 metabolic acidemia is associated with neonatal encephalopathy but not with neonatal
305 seizures alone: a population-based clinical audit. Acta Obstet Gynecol Scand 2014; 93:
306 477–482.

307 7. Badawi N, Felix JF, Kurinczuk JJ, Dixon G, Watson L, Keogh JM, Valentine J,
308 Stanley FJ. Cerebral palsy following term newborn encephalopathy: a population-based
309 study. Dev Med Child Neurol 2005; 47: 293-8.

310 8. Plauche WC. Subgaleal haematoma: a complication of instrumental delivery. JAMA

311 1980; 244: 1597–1598.

312 9. Chang H-Y, Peng C-C, Kao H-A, Hsu C-H, Hung H-Y, Chang J-H. Neonatal
313 subgaleal hemorrhage: clinical presentation, treatment, and predictors of poor prognosis.
314 Pediatr Int 2007; 49: 903–907.

315 10. Kuban KCK, Leviton A. Cerebral palsy. N Engl J Med 1994; 330:188-95.

316 11. Surveillance of Cerebral Palsy in Europe (SCPE). Surveillanceof cerebral palsy in
317 Europe: a collaboration of cerebral palsy surveys and registers. Dev Med Child Neurol
318 2000; 42: 816-24.

319 12. Badawi N, Kurinczuk JJ, Keogh JM, Alessandri LM, O'Sullivan F, Burton PR,
320 Pemberton PJ, Stanley FJ. Antepartum risk factors for newborn encephalopathy: the
321 Western Australian case-control study. BMJ 1998; 317: 1549-53.

322 13. Badawi N, Kurinczuk JJ, Keogh JM, Alessandri LM, O'Sullivan F, Burton PR,
323 Pemberton PJ, Stanley FJ. Intrapartum risk factors for newborn encephalopathy: the
324 Western Australian case-control study. BMJ 1998; 317: 1554-58.

325 14. Japanese version of "Guidelines for obstetrical practice in Japan: Japan Society of
326 Obstetrics and Gynecology (JSOG) and Japan Association of Obstetricians and
327 Gynecologists (JAOG) 2014 edition. page 246, Kyorin-sya, Tokyo

328 15. Morikawa M, Cho K, Yamada T, Yamada T, Sato S, Minakami H. Do uterotonic
329 drugs increase risk of abruptio placentae and eclampsia? Arch Gynecol Obstet 2014;
330 289: 987-91.

16. Gaffney G, Sellers S, Flavell V, Squier M, Johnson A. Case-control study of intrapartum care, cerebral palsy, and perinatal death. BMJ 1994; 308:7 43-50.

17. West CR, Curr L, Battin MR, Harding JE, Mccowan LM, Belgrave S, David B. Knight DB, Westgate JA. Antenatal antecedents of moderate or severe neonatal encephalopathy in term infants – a regional review. Aust N Z J Obstet Gynaecol 2005; 45: 207–210.

18. Draper ES, Kurinczuk JJ, Lamming CR, Clarke M, James D, Field D. A confidential enquiry into cases of neonatal encephalopathy. Arch Dis Child Fetal Neonatal Ed 2002; 87: F176–F180.

19. Towner D, Castro MA, Eby-Wilkens E, Gilbert WM. Effect of mode of delivery in nulliparous women on neonatal intracranial injury. N Engl J Med 1999; 341: 1709 – 14.

20. Chadwick LM, Pemberton PJ, Kurinczuk JJ. Neonatal subgaleal haematoma: associated risk factors, complications and outcome. J Paediatr Child Health 1996; 32: 228-32.

21. Uchil D, Arulkumaran S. Neonatal subgaleal hemorrhage and its relationship to delivery by vacuum extraction. Obstet Gynecol Surv 2003; **58**: 687–93.

22. Benjamin B, Khan MR. Pattern of external birth trauma in southwestern Saudi Arabia. J Trauma 1993; 35: 737–741.

23. Clark SL, Belfort MA, Gary D. Hankins V, Meyers, JA, Houser FM. Variation in the rates of operative delivery in the United States. Am J Obstet Gynecol 2007; 196: 526.e1-526.e5.

352 24. Elvander C, Ekeus C, Gemzell-Danielsson K, Cnattingius S. Reason for the
353 increasing use of vacuum extraction in Sweden: a population-based study. Acta Obstet
354 Gynecol Scand 2013; 92: 1175–82.

355 25. Mann JR, McDermotta S, Griffitha MI, Hardinc J, and Gregg A. Uncovering the
356 complex relationship between pre-eclampsia, preterm birth and cerebral palsy. Paediatr
357 Perinatl Epidemiol 2010; 25; 100–10.

358 26. Minakami H, Maeda T, Fujii T, Hamada H, Iitsuka Y, Itakura A, Itoh H, Iwashita M,
359 Kanagawa T, Kanai M, Kasuga Y, Kawabata M, Kobayashi K, Kotani T, Kudo Y,
360 Makino Y, Matsubara S, Matsuda H, Miura K, Murakoshi T, Murotsuki J, Ohkuchi A,
361 Ohno Y, Ohshiba Y, Satoh S, Sekizawa A, Sugiura M, Suzuki S, Takahashi T,
362 Tsukahara Y, Unno N, Yoshikawa H. Guidelines for obstetrical practice in Japan: Japan
363 Society of Obstetrics and Gynecology (JSOG) and Japan Association of Obstetricians
364 and Gynecologists (JAOG) 2014 edition. J Obstet Gynaecol Res. 2014; 40:1469-99.

**Table 1. Suboptimal intrapartum cares seen in 40 cases**

| | |
|---|---|
| 1. Delayed reaction to NRFS due to misinterpretation of FHR tracing | n=38 |
| 1) FHR pattern of level ≥ 4 lasting for a considerable time | n=35 |
| 2) FHR pattern of level 5 lasting for ≥ 120 min | n=5 |
| Sentinel events (FHR patterns) seen in the 38 women | |
| Decreased FHR baseline variability | n=23 |
| with recurrent late deceleration | n=17 |
| with recurrent variable deceleration | n=15 |
| with prolonged deceleration | n=20 |
| Normal FHR baseline variability | n=15 |
| with recurrent late deceleration | n=9 |
| with recurrent variable deceleration | n=11 |
| with prolonged deceleration | n=15 |
| 2. Inappropriate TOID | n=4 |
| 1) Before full dilatation of the uterine cervix | n=4 |
| 2) Before fetal head engagement | n=3 |

**Table 2. Apgar scores in 40 and 30 cases with and without suboptimal cares**

| | 1 min Apgar score | | | 5 min Apgar score | | |
|---|---|---|---|---|---|---|
| | < 3 | < 5 | < 7 | < 3 | < 5 | < 7 |
| Suboptimal care (n=40) | 29 (73%) | 37 (93%) | 39 (98%) | 14 (35%) | 27 (68%) | 38 (95%) |
| No suboptimal care (n=30) | 21 (70%) | 27 (90%) | 29 (97%) | 10 (33%) | 20 (67%) | 26 (87%) |
| Overall (n=70) | 50 (71%) | 64 (91%) | 68 (97%) | 24 (34%) | 47 (67%) | 64 (91%) |

No significant differences in frequency of low Apgar scores between two groups with and without suboptimal care

**Table 3. Demographic characteristis of study subjects**

| | Case (n=70) | Control (n=210) | *P*-value |
|---|---|---|---|
| Gestational week at delivery | 39.4±1.2 | 39.4±1.2 | >0.9999 |
| 36 | 2 (2.9%) | 6 (2.9%) | >0.9999 |
| 37 - 38 | 10 (14.3%) | 30 (14.3%) | >0.9999 |
| 39 - 40 | 45 (64.3%) | 137 (65.25) | 0.8852 |
| 41 | 13 (18.6%) | 37 (17.6%) | 0.8570 |
| ≥42 | 0 (0.0%) | 0 (0.0%) | >0.9999 |
| Nulliparous women | 53 (75.7%) | 160 (76.2%) | >0.9999 |
| Use of uterotonics | 38 (54.3%) | 114 (54.3%) | >0.9999 |
| Oxytocin alone | 25 (35.7%) | 82 (39.0%) | 0.6714 |
| Prostaglandins alone | 6 (8.6%) | 9 (4.3%) | 0.2168 |
| Both | 7 (10%) | 23 (11.0%) | 0.8238 |
| Rupture of fetal membranes* | 24 (34.3%) | 54 (25.7%) | 0.1659 |
| Trial of instrumental delivery (TOID) | 32 (45.7%) | 26 (12.4%) | <0.0001 |
| Successful TOID | 24 (34.3%) | 26 (12.4%) | <0.0001 |
| Failed TOID | 8 (11.4%) | 0 (0.0%) | <0.0001 |
| Emergent caesarean section | 24 (34.3%) | 30 (14.3%) | 0.0002 |
| Suboptimal intrapartum cares | 40 (57%) | 0 (0.0%) | <0.0001 |
| Hyperglycemia† | 3 (4.3%) | 5 (2.4%) | 0.4076 |
| Hypertensive disorders¶ | 8 (11%) | 5 (2.4%) | 0.0018 |
| | | | |
| Birth-weight (g) | 3099 ± 404 | 3031 ± 355 | 0.1809 |
| ≥ 3200 | 25 (35.7%) | 66 (31.4%) | 0.5073 |
| ≥ 3500 | 12 (17.1%) | 19 (9.0%) | 0.0616 |
| ≥ 3800 | 6 (8.6%) | 4 (1.9%) | 0.0092 |
| ≥ 4000g | 1 (1.4%) | 1 (0.5%) | 0.4382 |
| Subgaleal hemorrhage (SGH) | 11 (15.7%) | 0 (0.0%) | <0.0001 |

*, Rupture of fetal membranes was found on admission to hospital for delivery.
†, Including gestational diabetes mellitus and diabetes mellitus.
¶, Including gestational hypertension and preeclampsia.

**Table 4. Independent risk factors for cerebral palsy following neonatal encephalopathy**

| | B | SE | OR (95%CI) | *P*-value |
|---|---|---|---|---|
| Suboptimal intrapartum care | 0.795 | 0.055 | 2.21 (1.99 – 2.47) | <0.001 |
| Hypertensive disorders | 0.182 | 0.086 | 1.20 (1.01 – 1.42) | 0.035 |
| Emergent cesarean section | 0.175 | 0.048 | 1.19 (1.08 – 1.31) | <0.001 |
| Successful TOID | 0.127 | 0.050 | 1.14 (1.03 – 1.25) | 0.012 |

$B_0$ (SE) was 0.072 (0.023) in this analysis.