# Perinatal Risk and Protective Factors for Pediatric Abusive Head Trauma: A Multicenter Case-Control Study

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**Objective** To estimate associations between factors recorded in pregnancy and the first week of life and subsequent abusive head trauma.

**Study design** Multicenter, retrospective case-control study of perinatal records from 142 cases of abusive head trauma and 550 controls, matched by date and hospital of birth from 1991 to 2010. Multiple logistic regression assessed the relationship between perinatal exposures and abusive head trauma.

**Results** The risk of abusive head trauma decreased with increasing maternal age (OR, 0.91 per year; 95% CI 0.85-0.97) and increasing gestational age at birth (OR 0.79 per week; 95% CI 0.69-0.91). Mothers of cases were more likely to be Māori (OR 4.61; 95% CI 1.98-10.78), to be single (OR 5.10; 95% CI 1.83-14.23), have recorded social concerns (OR 4.29; 95% CI 1.32-13.91), and have missing data for antenatal care, partner status, social concerns, and substance abuse (OR 13.53; 95% CI 2.39-76.47). Case mothers were more likely not to take supplements in pregnancy (OR 3.53; 95% CI 1.30-9.54), to have membrane rupture longer than 48 hours before delivery (OR 13.01; 95% CI 2.84-59.68), and to formula feed (OR for mixed breast and formula feeding 6.06; 95% CI 2.39-15.36) before postnatal discharge (median 3 days).

**Conclusions** Factors associated with subsequent abusive head trauma can be identified from routine perinatal records. Targeted interventions initiated perinatally could possibly prevent some cases of abusive head trauma. However, any plans for targeted prevention strategies should consider not only those with identified risk factors but also those for which data are missing. *(J Pediatr 2017;■■:■■-■■).*

Pediatric abusive head trauma is defined as "an injury to the skull or intracranial contents of an infant or young child (<5 years of age) because of inflicted blunt impact and/or violent shaking," often in the first months of life.[1,2] Despite acknowledged underestimation of the true incidence,[3] abusive head trauma is the leading cause of traumatic death and disability in infancy.[1,4]

Infant crying is an important trigger for abusive head trauma, and perinatal healthcare may provide an opportunity for prevention.[1] One program educating parents of all newborns about the dangers of shaking and ways to handle persistent infant crying described a reduction in the incidence of abusive head trauma,[5] but it has not been possible to replicate these results elsewhere.[6]

Other programs focus on families perceived to be "at risk" of a range of adverse outcomes. Best-known are the Nurse-Family Partnership and Healthy Families America.[7,8] The former is targeted at low income first-time mothers, who enroll early in pregnancy and receive home visits until the child is 2 years old.[7] The latter uses a 2-stage protocol to assess risk within 1 week of birth. Perinatal records are screened for 15 items. If this screen is positive or data are missing, a follow-up interview is conducted using the Family Stress Checklist. Depending on the risk assessment, paraprofessionals visit the home for up to 5 years.[8]

All newborn babies in New Zealand have access to a system of universal nurse-led home visiting, introduced first in 1907.[7,9] From 1998, a variety of paraprofessional programs loosely modeled on Healthy Families America were added, but are available in only 30 of 74 counties.[10] Although criteria for acceptance into these programs are similar to Healthy Families America, there is no systematic screening of health records and referrals are made ad hoc.[10] Recently, attention has focused on the possibility that such programs might be targeted better by predictive risk modeling using "big data" held by government agencies.[11]

| | |
|---|---|
| AUC | Area under the receiver operator characteristic curve |
| DHBs | District Health Boards |
| IPV | Intimate partner violence |

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For the purposes of targeted prevention, some assume that abusive head trauma is subject to "risk factors" identified in general studies of child maltreatment. However, abusive head trauma may reflect "unique phenomena for which at-risk populations. . . must be separately defined."[12] Studies specific to abusive head trauma consistently report some associations but provide limited support for many others.[2,4,13-18]

The aim of this study was, therefore, to examine data routinely available to perinatal healthcare providers, to identify factors associated with the occurrence of abusive head trauma, and to contribute to evidence that could inform targeted prevention programs.

## Methods

New Zealand has a population of 4.4 million with approximately 60 000 births per year. Most healthcare is distributed through 20 publicly funded District Health Boards (DHBs). Starship Children's Hospital is located in the largest city, Auckland (population 1.4 million).

### Study Design and Sample

This was a retrospective case-control study of hospital records. Ethics approval was obtained from the National Health and Disability Ethics Committee (NTX/09/02/002). Cases were admitted to Starship between January 1, 1991, and December 31, 2010, and identified from the hospital child protection team database. From a previous national study, we estimate that from 1991 to 2010 approximately 40% of cases of abusive head trauma nationwide were admitted to Starship.[19] Cases met 3 criteria: (1) age <2 years; (2) intracranial injury and/or skull fracture; and (3) abusive head trauma reported to statutory authorities. The diagnosis of abusive head trauma was reached through a rigorous multi-agency process described elsewhere.[20] Uncertain cases were not included. Birthplace was identified. Because of resource constraints, only the 9 DHBs where 5 or more cases were born were included. Controls were chosen by random number selector from babies born the same day in the same hospital. To maximize power, 4 controls were selected for each case.[21] In 2016, controls were checked with the Ministry of Health and statutory authorities to confirm that they did not sustain abusive head trauma up to the age of 5 years.

### Data Collection

In 2011 and 2012, data were collected retrospectively by study investigators directly from maternal and child perinatal records where the child was born, using the same data sources for cases and controls. Variables were classified in groups describing the mother (eg, age, partner status, ethnicity, deprivation index,[22] psychiatric history, substance use, and "other social history," a catch-all for explicit documented concern in clinical records about any social circumstances); the pregnancy (eg, parity, antenatal care, illness); the delivery (eg, type, complications); the child (eg, gestation, centiles, multiple birth, admission to special care baby unit, type of feeding at discharge); and referral for social support or statutory intervention. When data could not be found for a variable (either because they were not documented in the records, or the relevant records could not be found), they were categorized as unknown. Routine inquiry for intimate partner violence (IPV) has been mandated since 2002, but was documented so rarely that these data were not collected. We had no access to home visiting enrollment data and could not study the effect of home visiting on risk.

### Statistical Analyses

Data were analyzed in SAS software v 9.3 (SAS Institute, Cary, North Carolina) and tested for difference in frequency between cases and controls using $\chi^2$ test for categorical data and $t$ tests for continuous variables. Conditional logistic regression estimated univariable ORs and 95% CIs for variables of interest arranged in groups: the mother (11 variables), the pregnancy (25 variables), the delivery (10 variables), the child (14 variables), and referrals for social or statutory intervention (4 variables). More than 20% of data were unknown for 23 of 64 variables, so "unknown" was analyzed as a category within each variable (eg, yes, no, unknown), compared with the reference category for that variable.

Thirty-four variables significant at $P < .1$ in univariable analysis were included in group multivariable analysis. Each group was reduced stepwise, backward, and forward, to ensure robustness/consistency and determine how variables influenced each other.

Nineteen variables significant at $P < .05$ in group analyses were combined in a final model and reduced stepwise, backward, and forward. Unknown was associated with risk for some variables but not others. The best way to incorporate this in the model was by an additional variable, which counted the frequency of unknown in 4 variables where it was associated with risk. Variables which remained significant at $P < .05$ were retained.

To test validity and statistical precision, the final model was analyzed with both conditional and unconditional logistic regression.[23] The area under the receiver operating characteristic curve (AUC) and 95% CI were used to describe performance of the unconditional model.

Mean interval between deliveries was not included in the final model because it eliminated 265 primiparous women. It was significant in group analysis (31 months for cases, 38.8 for controls, $P = .026$) so we performed an additional analysis of the effect for multiparous women.

## Results

We identified 166 cases of abusive head trauma and included 142 (86%), excluding 10 with no obtainable birth records and 14 from 7 DHBs where less than 5 cases were born. We identified 568 controls and included 550 (97%), excluding 18 with no obtainable birth records. No controls sustained abusive head trauma up to the age of 5 years.

**Table I** presents comparative data between cases and controls selected for relevance with demographics or the final model. The results for all 64 variables included in logistic regression are detailed in **Table II** (available at www.jpeds.com).



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**Table I. Selected comparisons between cases and controls**

| Variables | Categories | Cases No. (%) | Controls No. (%) | *P* value |
|---|---|---|---|---|
| Mother variables | | | | |
| Age, y: mean/SD | | 25.3/6.1 | 29.5/6.0 | <.001 |
| New Zealand Deprivation Index* | 1-3 | 10 (7.0) | 88 (16.0) | .002 |
| | Unknown | 7 (4.9) | 34 (6.2) | |
| | 4-7 | 35 (24.6) | 171 (31.1) | |
| | 8-10 | 90 (63.4) | 257 (46.7) | |
| Substance abuse† | No | 50 (35.2) | 381 (69.3) | <.001 |
| | Unknown | 81 (57.0) | 155 (28.2) | |
| | Yes | 11 (7.7) | 14 (2.5) | |
| Pregnancy variables | | | | |
| Antenatal care provider‡ | GP/Ob/shared | 19 (13.4) | 135 (24.5) | <.001 |
| | Private midwife | 63 (44.4) | 253 (46.0) | |
| | Public | 46 (32.4) | 147 (26.7) | |
| | No care | 4 (2.8) | 6 (1.1) | |
| | Unknown | 10 (7.0) | 9 (1.6) | |
| Booking§ | Yes | 109 (76.8) | 487 (88.5) | .003 |
| | No | 7 (4.9) | 15 (2.7) | |
| | Unknown | 26 (18.3) | 48 (8.7) | |
| Child variables | | | | |
| Case age at admission, mo: mean/SD | | 6.2/4.7 | | |
| Case fatalities | | 16 (11.3) | | |
| Place of birth | Auckland | 101 | 395 | |
| | Other | 41 | 155 | |
| Sex | Female | 55 (38.7) | 260 (47.3) | .07 |
| | Male | 87 (61.3) | 290 (52.7) | |
| Birthweight, z score, mean | | 0.06 | 0.28 | .06 |
| Gestation, wk: mean/SD | | 37/3.4 | 39/1.8 | <.001 |

*GP*, general practitioner; *Ob*, obstetrician

*Number from 1-10; 1-3 is least deprived, 8-10 is most deprived. Derived from address and 9 census variables (receiving a means-tested benefit, living in a household below an equivalized income threshold, not living in own home, single parent family, unemployed, no qualification obtained from a completed course of at least 3 months of full time study, living in a household below an equivalized bedroom occupancy threshold, with no access to a telephone, with no access to a car).

†Any disclosure made of substance abuse, including alcohol or drugs. Defined as having required engagement with alcohol and drug services.

‡All care from GP, all care from private Ob, shared antenatal care with GP but hospital managed delivery and postnatal care (shared), all care from private midwife, all care from hospital (public).

§Whether the mother registered for antenatal care at any time before delivery.

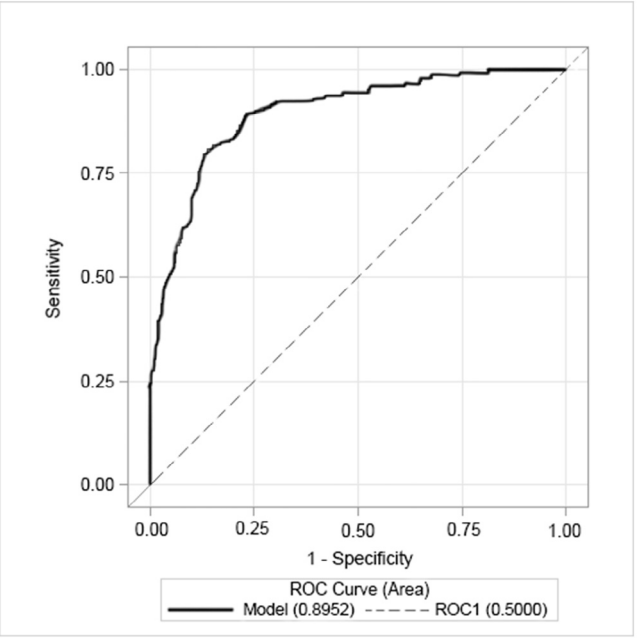


**Figure.** AUC. *ROC*, receiver operating dharacteristic.

The final model included 9 variables which remained significant whether analyzed conditionally or unconditionally (**Table III**), although the unconditional model had greater statistical precision.[23] The AUC was 89.5% (95% CI 86.6-92.5) (**Figure**).

The mothers of cases were on average 4 years younger than the mothers of controls (25.3 vs 29.5 years, **Table I**). Each additional year of maternal age reduced the risk of abusive head trauma by a factor of 0.91 (95% CI 0.85-0.97, **Table III**), such that the risk for a baby born to a 25-year-old was one-half that for a baby born to an 18-year-old. Mothers of cases were more likely to be indigenous Māori (OR 4.61; 95% CI 1.98-10.78), to have "other social history" (OR 4.29; 95% CI 1.32-13.91), and to be unmarried, single mothers being associated with the greatest risk (OR 5.1; 95% CI 1.83-14.23).

The categorical variable with the highest OR for abusive head trauma was counted unknowns in the variables of "booking" (whether the mother registered for antenatal care), other social history, partner status, and substance abuse. Risk increased 5-fold for 1 piece of unknown data (OR 5.75; 95% CI 2.27-14.59) and 13-fold for 2 or more (OR 13.53; 95% CI 2.39-76.47).

Maternal variables not found to be significant included alcohol or drug use, medical or psychiatric history, smoking, and socioeconomic status.

In the final model, mothers of cases were more likely not to take supplements (nonprescribed medications) in pregnancy (OR 3.53; 95% CI 1.3-9.54). In the analysis for multiparous women, shorter inter-pregnancy intervals remained significantly associated with abusive head trauma ($P = .029$), OR 0.76 (95% CI 0.59-0.98) per year. The risk for a second baby born after 3 years was less than one-half that for one born after 1 year. Most variables describing the pregnancy (other than unknown registration for antenatal care) were not significant. This included parity and the type of antenatal care provider.

In regard to the delivery, only 1 variable, rupture of membranes for longer than 48 hours, remained in the final model: 8.5% of cases and 2.0% of controls (OR 13.01; 95% CI 2.84-59.68).

Finally, in reference to the child, cases had a gestational age at delivery that was on average 2 weeks less than controls (37 vs 39 weeks, **Table I**). Each additional week in utero reduced the risk of abusive head trauma by a factor of 0.79 (95% CI 0.69-0.91), such that the risk of abusive head trauma for a newborn of 38 weeks gestation was less than a one-third of the risk for a newborn of 33 weeks gestation.

If a newborn was not drinking breast milk only at the time of discharge (median 3 days), the risk of abusive head trauma increased 4-fold or more: OR 4.53 for formula alone (95% CI 1.67-12.28) and OR 6.06 for formula and breast milk (95% CI 2.39-15.36).



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**Table III. Variables remaining in the final multivariable model**

| Variables | Categories | Cases No. (%) | Controls No. (%) | Conditional multivariable OR (95% CI) | Unconditional multivariable OR (95% CI) |
|---|---|---|---|---|---|
| Maternal age (per y) | | | | 0.91 (0,85, 0.97) | 0.92 (0.88, 0.96) |
| Ethnicity* | European | 31 (21.8) | 255 (46.4) | 1.00 | 1.00 |
| | Pacific | 25 (17.6) | 115 (20.9) | 2.17 (0.92, 5.14) | 1.92 (0.93, 3.98) |
| | Asian | 5 (3.5) | 50 (9.1) | 2.13 (0.62, 7.38) | 2.06 (0.64, 6.63) |
| | Other | 3 (2.1) | 23 (4.2) | 1.47 (0.18, 12.00) | 2.33 (0.39, 13.74) |
| | Māori | 78 (54.9) | 107 (19.5) | 4.61 (1.98, 10.78) | 3.97 (2.12, 7.44) |
| Other social history† | No | 67 (47.2) | 444 (80.7) | 1.00 | 1.00 |
| | Unknown | 57 (40.1) | 89 (16.2) | 2.29 (0.49, 10.72) | 1.27 (0.37, 4.35) |
| | Yes | 18 (12.7) | 17 (3.1) | 4.29 (1.32, 13.91) | 4.62 (1.81, 11.80) |
| Partner status | Married | 27 (19.0) | 309 (56.2) | 1.00 | 1.00 |
| | Unknown | 24 (16.9) | 46 (8.4) | 1.90 (0.65, 5.56) | 2.04 (0.91, 4.60) |
| | De facto‡ | 45 (31.7) | 111 (20.2) | 3.10 (1.23, 7.83) | 3.27 (1.59, 6.74) |
| | Single | 46 (32.4) | 84 (15.3) | 5.10 (1.83, 14.23) | 3.7 (1.71, 8.03) |
| Unknowns§ | 0 | 47 (33.1) | 372 (67.6) | 1.00 | 1.00 |
| | 1 vs 0 | 40 (28.2) | 95 (17.3) | 5.75 (2.27, 14.59) | 3.89 (2.02, 7.50) |
| | 2+ vs 0 | 55 (38.7) | 83 (15.1) | 13.53 (2.39, 76.47) | 7.96 (2.06, 30.71) |
| Supplements¶ | Yes | 19 (13.4) | 130 (23.6) | 1.00 | 1.00 |
| | Unknown | 69 (48.6) | 222 (40.4) | 2.44 (0.94, 6.33) | 1.06 (0.51, 2.20) |
| | No | 54 (38.0) | 188 (34.2) | 3.53 (1.30, 9.54) | 2.73 (1.29, 5.79) |
| Prolonged rupture of membranes** | No | 108 (76.1) | 503 (91.5) | 1.00 | 1.00 |
| | Unknown | 22 (15.5) | 36 (6.5) | 0.99 (0.34, 2.87) | 0.99 (0.43, 2.28) |
| | Yes | 12 (8.5) | 11 (2.0) | 13.01 (2.84, 59.68) | 6.53 (2.10, 20.30) |
| Gestation (per wk) | | | | 0.79 (0.69, 0.91) | 0.77 (0.69, 0.86) |
| Feeding†† | Breastmilk | 65 (45.8) | 432 (78.5) | 1.00 | 1.00 |
| | Unknown | 10 (7.0) | 10 (1.8) | 5.82 (1.31, 25.81) | 3.93 (1.17, 13.18) |
| | Formula | 36 (25.4) | 49 (8.9) | 4.53 (1.67, 12.28) | 4.25 (2.18, 8.29) |
| | Both | 31 (21.8) | 59 (10.7) | 6.06 (2.39, 15.36) | 4.74 (2.42, 9.28) |

*Ethnicity. Participant-defined. If multiple, prioritized as Māori, Pacific, Asian, Other, European.
†Other social history. Any social concern documented in clinical notes. Examples: attempted suicide, child in care, child protective services involved, partner in jail, prostitution, single parent, social worker involved.
‡De facto. Living together as a couple but not married.
§Unknowns in substance abuse history, other social history, partner status, and booking.
¶Supplements. Any medication not usually prescribed (eg, folate, vitamins, iron [if not prescribed for anemia]).
**Membrane rupture more than 48 hours before delivery.
††Pattern of feeding in 24 hours before discharge. Breast includes expressing.

Variables pertaining to the child not found to be significant included admission to Special Care Baby Unit, birth type (singleton or twin), birth weight, and sex.

No variable remained significant in the final model regarding referral for social support or statutory intervention.

## Discussion

Others have examined the relationship between perinatal data and risk of child maltreatment,[24,25] but our case-control study directly relates such data to the risk of abusive head trauma. Our study complies with recommended methodologic standards.[26] Importantly, this study confirms that information predictive of the risk of abusive head trauma can be obtained from perinatal data routinely collected by health professionals. The AUC of 89.5% quantified how well our model identified the population of newborns at risk of abusive head trauma. For comparison, a recent national "Predictive Risk Model" for substantiated maltreatment by the age of 5 years used 132 variables derived from public benefit records for 57 986 children and achieved an AUC of 76%.[11]

The validity of our findings is supported by the fact that the increased risk observed for single or young mothers and preterm delivery is consistent with the literature, both for child maltreatment in general[25,27] and specific to abusive head trauma[13-16,18] although, unlike some studies,[25,27] after adjusting for preterm delivery, we found no association with birth weight. Similarly, there is a recognized association between short inter-pregnancy interval and child maltreatment.[25]

It should be noted that New Zealand perinatal records collect no information on parental education, although "without any educational qualification" is 1 variable in the New Zealand Deprivation Index.[22]

In this study, the effect of multiple birth seen in univariable analyses was no longer statistically significant in the final model. Multivariable analysis found multiple birth was accounted for by adjusting for gestational age.[14,16] An effect of gestational age was first suggested in 1998 when Becker et al[28] drew attention to possible mechanisms for increased risk in preterm infants, such as interrupted attachment and biomechanical vulnerability. A large study confirming the association between gestational age and maltreatment proposed additional hypotheses including parental hostility or an unidentified common pathway, emphasizing that any explanation must address the fact that the association spans "the whole range of. . .gestational age, not simply. . .the extremes."[27]

Poverty is often reported as a risk factor for abusive head trauma.[13,16,17] One study, using the Scottish Index of Multiple Deprivation, concluded that abusive head trauma "is



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essentially. . .a disorder of urban deprivation."[16] We used a deprivation index to assess the influence of poverty, but the evidence for this association was weak. Although this may reflect the limitations of applying area-based indices to individuals,[22] it is consistent with other matched case-control studies[29,30] and suggests the variables in our final model are not simply indirect measures of the effect of poverty. From the perspective of prevention, this does not imply that strategies to reduce poverty will have no effect on the incidence of abusive head trauma. However, it suggests there are other factors associated with the risk of abusive head trauma, which may be modifiable through other prevention strategies.

The literature varies on the relationship between abusive head trauma and ethnicity,[4,13-15,17,18] but increased risk for Māori is consistent with other New Zealand data and may reflect complex intergenerational effects of colonization.[31] Our study shows that ethnicity is not explained by variables available in perinatal records. The mediating mechanisms might be clearer if comprehensive data about access to healthcare, psychosocial factors, and structural determinants of health were routinely collected.

The association between abusive head trauma and "other social history" is important.[24] There was no indication in the records that staff who recorded concerns were anticipating abusive head trauma — they were documenting issues, which they believed created a general risk. This suggests that health professionals can recognize risk and that abusive head trauma shares a risk profile with other adverse outcomes. However, the fact that the act of recording concerns was associated with risk of abusive head trauma emphasizes the potential futility of recognizing risk if there is no intervention to reduce it.

The observation that staff can recognize risk must be balanced by the observation that documented routine psychosocial assessment was often of poor quality: data on alcohol and drug use, substance abuse, and mental illness were often unknown, with the result that we cannot specifically conclude anything about the relationship of those factors to abusive head trauma.

An association between not taking supplements in pregnancy and risk of abusive head trauma has not previously been described. Our analysis included known potential confounders, but 1 possible explanation is unplanned pregnancy, a common reason for not taking folate[32] and a risk factor for maltreatment,[25] but not a question routinely recorded during pregnancy in New Zealand.

The association with prolonged rupture of membranes is also a new finding and remained significant after controlling for known potential confounders.[33] Abdominal trauma or coitus may trigger rupture and physical and sexual assault are strongly correlated manifestations of IPV.[34] One possible hypothesis is that the association reflects undisclosed antepartum trauma.[35]

The finding of risk associated with formula feeding in the first week of life is also novel, although 1 large 15-year cohort study showed a 4-fold increase in the odds of child maltreatment (particularly neglect) for children breastfed for less than 4 months, possibly reflecting poor attachment.[36] New Zealand has a relatively high rate of breastfeeding,[37] and successful decisions to breastfeed originate early in pregnancy, heavily influenced by maternal support systems.[38] The association in our study may reflect variables absent from our data, which affect the ability of women to plan for breastfeeding, such as support from their partner,[38] past history of abuse as a child, or IPV.[39] It is a limitation of this study that (other than maternal partner status) New Zealand perinatal records collect no information about the child's father or mother's partner.

Our study has also shown the extent of the problem of missing data (unknowns). Although data may have been obtained and not recorded or recorded elsewhere,[40] their absence from accessible records would make systematic screening difficult to implement. The absence of data on IPV is particularly concerning, given the strong association of IPV with child maltreatment[41] and the fact that it may render home visiting ineffective in child maltreatment prevention.[42]

The amount of missing data is a major limitation of this study. However, it enabled us to study "unknown" as a variable in its own right and alerted us to the relationship with risk. This may reflect minimal or fragmented antenatal care, poor relationships with healthcare providers, reluctance to ask difficult questions of high-risk families,[40,43,44] or the influence of other variables such as IPV.[45] Whatever the explanation, prevention strategies should consider not only families with identified risk factors but also those where data are missing.

Despite the high AUC and the fact that our model has significant predictive value, we do not suggest that our study provides an adequate framework (eg, appropriate sensitivity and specificity) for predicting risk in individual families.[46] It must be emphasized that more research is required to replicate our findings and clarify their significance. We cannot, for example, exclude the possibility of residual confounding from measured or unmeasured factors.

Our findings nevertheless provide insight on a range of factors associated with abusive head trauma that are identifiable perinatally. This does not imply that targeted approaches would be superior to universal approaches to the prevention of abusive head trauma. As others note, there are good reasons to implement universal or community-based strategies where such strategies are supported by evidence.[47] Our data suggest that strategies designed, for example, to reduce the incidence of teenage pregnancy or preterm delivery, promote breastfeeding, and lengthen inter-pregnancy interval may have a significant effect on the incidence of abusive head trauma. However, targeted programs are often implemented. We provide evidence that systematic assessment of risk factors by perinatal healthcare providers could help ensure that such programs are provided to those most at risk. ■

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## References


1. Parks S, Annest J, Hill H, Karch D. Pediatric abusive head trauma: recommended definitions for public health surveillance and research. Atlanta (GA): Centers for Disease Control and Prevention; 2012.
2. Parks S, Sugerman D, Xu L, Coronado V. Characteristics of non-fatal abusive head trauma among children in the USA, 2003-2008: application of the CDC operational case definition to national hospital inpatient data. Inj Prev 2012;18:392-8.
3. Theodore AD, Chang JJ, Runyan DK, Hunter WM, Bangdiwala SI, Agans R. Epidemiologic features of the physical and sexual maltreatment of children in the Carolinas. Pediatrics 2005;115:e331-7.
4. Parks SE, Kegler SR, Annest JL, Mercy JA. Characteristics of fatal abusive head trauma among children in the USA: 2003-2007: an application of the CDC operational case definition to national vital statistics data. Inj Prev 2012;18:193-9.
5. Dias MS, Smith K, DeGuehery K, Mazur P, Li V, Shaffer ML. Preventing abusive head trauma among infants and young children: a hospital-based, parent education program. Pediatrics 2005;115:e470-7.
6. Zolotor AJ, Runyan DK, Shanahan M, Durrance CP, Nocera M, Sullivan K, et al. Effectiveness of a statewide abusive head trauma prevention program in North Carolina. JAMA Pediatr 2015;169:1126-31.
7. Finello KM, Terteryan A, Riewerts RJ. Home visiting programs: what the primary care clinician should know. Curr Probl Pediatr Adolesc Health Care 2016;46:101-25.
8. Duggan A, Windham A, McFarlane E, Fuddy L, Rohde C, Buchbinder S, et al. Hawaii's healthy start program of home visiting for at-risk families: evaluation of family identification, family engagement, and service delivery. Pediatrics 2000;105:250-9.
9. Royal New Zealand Plunket Society [homepage on the internet]. Wellington: plunket society; 2017. https://www.plunket.org.nz/what-we-do/who-we-are/our-history/. Accessed February 13, 2017.
10. Vaithianathan R, Wilson M, Maloney T, Baird S. The impact of the family start home visiting programme on outcomes for mothers and children. a quasi-experimental study. Wellington: Ministry of Social Development; 2016.
11. Vaithianathan R, Maloney T, Putnam-Hornstein E, Jiang N. Children in the public benefit system at risk of maltreatment: identification via predictive modeling. Am J Prev Med 2013;45:354-9.
12. Davies WH, Garwood MM. Chapter four: who are the perpetrators and why do they do it? J Aggress Maltreat Trauma 2001;5:41-54.
13. Gumbs GR, Keenan HT, Sevick CJ, Conlin AM, Lloyd DW, Runyan DK, et al. Infant abusive head trauma in a military cohort. Pediatrics 2013;132:668-76.
14. Keenan HT, Runyan DK, Marshall SW, Nocera MA, Merten DF, Sinal SH. A population-based study of inflicted traumatic brain injury in young children. JAMA 2003;290:621-6.
15. Kesler H, Dias MS, Shaffer M, Rottmund C, Cappos K, Thomas NJ. Demographics of abusive head trauma in the Commonwealth of Pennsylvania. J Neurosurg Pediatr 2008;1:351-6.
16. Mok JY, Jones PA, Myerscough E, Shah AR, Minns RA. Non-accidental head injury: a consequence of deprivation? J Epidemiol Community Health 2010;64:1049-55.
17. Niederkrotenthaler T, Xu L, Parks SE, Sugerman DE. Descriptive factors of abusive head trauma in young children—United States, 2000-2009. Child Abuse Negl 2013;37:446-55.
18. Parrish J, Baldwin-Johnson C, Volz M, Goldsmith Y. Abusive head trauma among children in Alaska: a population-based assessment. Int J Circumpolar Health 2013;72.
19. Kelly P, Farrant B. Shaken baby syndrome in New Zealand, 2000-2002. J Paediatr Child Health 2008;44:99-107.
20. Kelly P, John S, Vincent AL, Reed P. Abusive head trauma and accidental head injury: a 20-year comparative study of referrals to a hospital child protection team. Arch Dis Child 2015;100:1123-30.
21. Grimes DA, Schulz KF. Compared to what? Finding controls for case-control studies. Lancet 2005;365:1429-33.
22. White P, Gunston J, Salmond C, Atkinson J, Crampton P. Atlas of socioeconomic deprivation in New Zealand NZDep2006. Wellington: 2008.
23. Pearce N. Analysis of matched case-control studies. BMJ 2016;352:i969.
24. Leventhal JM, Garber RB, Brady CA. Identification during the postpartum period of infants who are at high risk of child maltreatment. J Pediatr 1989;114:481-7.
25. Thompson EL, Thompson LA, Black EW, Esernio-Jenssen D, Hardt N, Das R, et al. Identifying indicators during pregnancy for child maltreatment. Matern Child Health J 2013;17:1817-24.
26. von Elm E, Altman DG, Egger M, Pocock SJ, Gotzsche PC, Vandenbroucke JP, et al. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Lancet 2007;370:1453-7.
27. Spencer N, Wallace A, Sundrum R, Bacchus C, Logan S. Child abuse registration, fetal growth, and preterm birth: a population based study. J Epidemiol Community Health 2006;60:337-40.
28. Becker JC, Liersch R, Tautz C, Schlueter B, Andler W. Shaken baby syndrome: report on four pairs of twins. Child Abuse Negl 1998;22:931-7.
29. Altemeier WA, O'Connor S, Vietze PM, Sandler HM, Sherrod KB. Antecedents of child abuse. J Pediatr 1982;100:823-9.
30. Smith JA, Adler RG. Children hospitalized with child abuse and neglect: a case-control study. Child Abuse Negl 1991;15:437-45.
31. Wharewera-Mika J, Cooper E, Kool B, Pereira S, Kelly P. Caregivers' voices: The experiences of caregivers of children who sustained serious accidental and non-accidental head injury in early childhood. Clin Child Psychol Psychiatry 2016;21:268-86.
32. Bixenstine PJ, Cheng TL, Cheng D, Connor KA, Mistry KB. Association between preconception counseling and folic acid supplementation before pregnancy and reasons for non-use. Matern Child Health J 2015;19:1974-84.
33. Allen SR. Epidemiology of premature rupture of the fetal membranes. Clin Obstet Gynecol 1991;34:685-93.
34. Parrish JW, Young MB, Perham-Hester KA, Gessner BD. Identifying risk factors for child maltreatment in Alaska: a population-based approach. Am J Prev Med 2011;40:666-73.
35. Shumway J, O'Campo P, Gielen A, Witter FR, Khouzami AN, Blakemore KJ. Preterm labor, placental abruption, and premature rupture of membranes in relation to maternal violence or verbal abuse. J Matern Fetal Med 1999;8:76-80.
36. Strathearn L, Mamun AA, Najman JM, O'Callaghan MJ. Does breastfeeding protect against substantiated child abuse and neglect? A 15-year cohort study. Pediatrics 2009;123:483-93.
37. Victora CG, Bahl R, Barros AJ, Franca GV, Horton S, Krasevec J, et al. Breastfeeding in the 21st century: epidemiology, mechanisms, and lifelong effect. Lancet 2016;387:475-90.
38. Brand E, Kothari C, Stark MA. Factors related to breastfeeding discontinuation between hospital discharge and 2 weeks postpartum. J Perinat Educ 2011;20:36-44.
39. Sorbo MF, Lukasse M, Brantsaeter AL, Grimstad H. Past and recent abuse is associated with early cessation of breast feeding: results from a large prospective cohort in Norway. BMJ Open 2015;5:e009240.
40. Barnes J, Howden B, Niven L, Ball M. Eligibility for the Family Nurse Partnership programme Testing new criteria. London: Institute for the Study of Children, Families and Social Issues, Birkbeck, University of London; 2012.
41. Browne KD, Jackson V. Community intervention to prevent child maltreatment in England: evaluating the contribution of the Family Nurse Partnership. J Public Health (Bangkok) 2013;35:447-52.
42. Eckenrode J, Ganzel B, Henderson CR Jr, Smith E, Olds DL, Powers J, et al. Preventing child abuse and neglect with a program of nurse home




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visitation: the limiting effects of domestic violence. JAMA 2000;284:1385-91.
43. Orkow B. Implementation of a family stress checklist. Child Abuse Negl 1985;9:405-10.
44. Kerker BD, Horwitz SM, Leventhal JM. Patients' characteristics and providers' attitudes: predictors of screening pregnant women for illicit substance use. Child Abuse Negl 2004;28:209-23.
45. Cha S, Masho SW. Intimate partner violence and utilization of prenatal care in the United States. J Interpers Violence 2014;29:911-27.
46. Ware JH. The limitations of risk factors as prognostic tools. N Engl J Med 2006;355:2615-7.
47. Daro D, Dodge KA. Creating community responsibility for child protection: possibilities and challenges. Future Child 2009;19:67-93.



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**Table II. Variables included in logistic regression**

| Variables | Categories | Cases No. (%) | Controls No. (%) | *P* value | Univariable OR (95% CI) | Multivariable Step 1 | Multivariable Step 2 |
|---|---|---|---|---|---|---|---|
| Mother variables | | | | | | | |
| Alcohol* | No | 77 (54.2) | 341 (62.0) | .13 | 1.00 | Yes | |
| | Unknown | 49 (34.5) | 171 (31.1) | | 1.35 (0.82, 2.22) | | |
| | Yes | 16 (11.3) | 38 (6.9) | | 1.89 (0.99, 3.58) | | |
| Drugs* | No | 85 (59.9) | 340 (61.8) | .51 | 1.00 | | |
| | Unknown | 51 (35.9) | 197 (35.8) | | 1.02 (0.63, 1.66) | | |
| | Yes | 6 (4.2) | 13 (2.4) | | 1.96 (0.68, 5.64) | | |
| Medical history† | Fit and well | 68 (47.9) | 340 (61.8) | .006 | 1.00 | Yes | |
| | Chronic illness | 47 (33.1) | 149 (27.1) | | 1.60 (1.05, 2.45) | | |
| | Unknown | 27 (19.0) | 61 (11.1) | | 2.31 (1.34, 3.99) | | |
| New Zealand Deprivation Index‡ | Least deprived 1-3 | 10 (7.0) | 88 (16.0) | .002 | 1.00 | Yes | |
| | Unknown | 7 (4.9) | 34 (6.2) | | 1.53 (0.51, 4.55) | | |
| | Intermediate 4-7 | 35 (24.6) | 171 (31.1) | | 1.74 (0.82, 3.70) | | |
| | Most deprived 8-10 | 90 (63.4) | 257 (46.7) | | 3.37 (1.64, 6.91) | | |
| Smoking | No | 60 (42.3) | 356 (64.7) | <.001 | 1.00 | Yes | Yes |
| | Unknown | 18 (12.7) | 66 (12.0) | | 1.66 (0.88, 3.14) | | |
| | Yes | 64 (45.1) | 128 (23.3) | | 3.02 (1.99, 4.59) | | |
| Psychiatric history*,† | No | 72 (50.7) | 399 (72.5) | <.001 | 1.00 | Yes | |
| | Yes | 8 (5.6) | 22 (4.0) | | 2.18 (0.91, 5.20) | | |
| | Unknown | 62 (43.7) | 129 (23.5) | | 4.55 (2.69, 7.67) | | |
| Ethnicity§ | Asian | 5 (3.5) | 50 (9.1) | <.001 | 0.82 (0.30, 2.21) | Yes | Yes |
| | European | 31 (21.8) | 255 (46.4) | | 1.00 | | |
| | Other | 3 (2.1) | 23 (4.2) | | 1.20 (0.33, 4.38) | | |
| | Pacific | 25 (17.6) | 115 (20.9) | | 1.88 (1.04, 3.39) | | |
| | Māori | 78 (54.9) | 107 (19.5) | | 6.66 (3.99, 11.15) | | |
| Partner status† | Married | 27 (19.0) | 309 (56.2) | <.001 | 1.00 | Yes | Yes |
| | De facto¶ | 45 (31.7) | 111 (20.2) | | 4.61 (2.69, 7.86) | | |
| | Unknown | 24 (16.9) | 46 (8.4) | | 6.04 (3.09, 11.79) | | |
| | Single | 46 (32.4) | 84 (15.3) | | 7.45 (4.18, 13.29) | | |
| Other social history*,†,** | No | 67 (47.2) | 444 (80.7) | <.001 | 1.00 | Yes | Yes |
| | Unknown | 57 (40.1) | 89 (16.2) | | 7.95 (4.54, 13.95) | | |
| | Yes | 18 (12.7) | 17 (3.1) | | 8.10 (3.78, 17.36) | | |
| Substance abuse*,†,†† | No | 50 (35.2) | 381 (69.3) | <.001 | 1.00 | Yes | Yes |
| | Unknown | 81 (57.0) | 155 (28.2) | | 8.33 (4.81, 14.42) | | |
| | Yes | 11 (7.7) | 14 (2.5) | | 11.27 (4.26, 29.82) | | |
| Age, mean, years | | 25.3 | 29.5 | <.001 | 0.88 (0.85, 0.92) | Yes | Yes |
| Pregnancy variables | | | | | | | |
| Diabetes* | Unknown | 40 (28.2) | 166 (30.2) | .09§ | | | |
| | No | 101 (71.1) | 365 (66.4) | | 1.00 | | |
| | Yes | 1 (0.7) | 19 (3.5) | | 0.24 (0.03, 1.86) | | |
| Polyhydramnios* | Unknown | 33 (23.2) | 140 (25.5) | .86 | 0.87 (0.55, 1.37) | | |
| | Yes | 2 (1.4) | 8 (1.5) | | 0.93 (0.19, 4.58) | | |
| | No | 107 (75.4) | 402 (73.1) | | 1.00 | | |
| Previous stillbirth | Unknown | 13 (9.2) | 62 (11.3) | .76 | 0.75 (0.38, 1.47) | | |
| | ≥1 | 1 (0.7) | 4 (0.7) | | 0.97 (0.11, 8.72) | | |
| | 0 | 128 (90.1) | 484 (88.0) | | 1.00 | | |
| Booking weight, mean, kg* | | 80.402 | 73.88 | .009§ | 1.02 (1.00, 1.03) | | |
| | Known | 75 (52.8) | 351 (63.8) | | | | |
| | Unknown | 67 (47.2) | 199 (36.2) | | | | |
| Booking gestation, mean, wk* | | 19.53 | 17.7 | .05§ | 1.03 (1.00, 1.06) | | |
| | Known | 100 (70.4) | 428 (77.8) | | | | |
| | Unknown | 42 (29.6) | 122 (22.2) | | | | |
| Previous terminations, No. | 1 | 25 (17.6) | 103 (18.7) | .93 | 0.93 (0.56, 1.52) | | |
| | 2 + | 16 (11.3) | 66 (12.0) | | 0.95 (0.52, 1.73) | | |
| | 0 | 94 (66.2) | 360 (65.5) | | 1.00 | | |
| | Unknown | 7 (4.9) | 21 (3.8) | | 1.25 (0.52, 3.00) | | |
| Hypertension* | Unknown | 30 (21.1) | 143 (26.0) | .34 | 0.78 (0.49, 1.24) | | |
| | No | 97 (68.3) | 364 (66.2) | | 1.00 | | |
| | Yes | 15 (10.6) | 43 (7.8) | | 1.38 (0.71, 2.69) | | |
| Admission <37/40 | Unknown | 6 (4.2) | 35 (6.4) | .26 | 0.66 (0.27, 1.63) | | |
| | No | 112 (78.9) | 447 (81.3) | | 1.00 | | |
| | Yes | 24 (16.9) | 68 (12.4) | | 1.44 (0.85, 2.44) | | |
| Previous preterm delivery | Unknown | 11 (7.7) | 54 (9.8) | .44 | 0.76 (0.37, 1.53) | | |
| | No | 116 (81.7) | 454 (82.5) | | 1.00 | | |
| | Yes | 15 (10.6) | 42 (7.6) | | 1.45 (0.77, 2.74) | | |

(*continued*)



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**Table II. Continued**

| Variables | Categories | Cases No. (%) | Controls No. (%) | *P* value | Univariable OR (95% CI) | Multivariable Step 1 | Multivariable Step 2 |
|---|---|---|---|---|---|---|---|
| Ultrasound at 20/40* | Yes | 63 (44.4) | 273 (49.6) | .35 | 1.00 | | |
| | Unknown | 48 (33.8) | 180 (32.7) | | 1.19 (0.76, 1.84) | | |
| | No | 31 (21.8) | 97 (17.6) | | 1.45 (0.87, 2.39) | | |
| Ultrasound at 13/40* | Yes | 31 (21.8) | 158 (28.7) | .13 | 1.00 (0.74, 2.07) | Yes | Yes |
| | Unknown | 49 (34.5) | 199 (36.2) | | 1.23 | | |
| | No | 62 (43.7) | 193 (35.1) | | 1.63 (0.99, 2.68) | | |
| Previous deliveries, No. | 1 | 38 (26.8) | 166 (30.2) | .15 | 0.93 (0.58, 1.47) | | |
| | 2 | 20 (14.1) | 88 (16.0) | | 0.94 (0.53, 1.68) | | |
| | 0 | 53 (37.3) | 212 (38.5) | | 1.00 | | |
| | 3 + | 31 (21.8) | 79 (14.4) | | 1.59 (0.94, 2.67) | | |
| | Unknown | 0 (0.0) | 5 (0.9) | | | | |
| Delivery interval, mean, months (422 multiparous women) | | 31.07 | 38.83 | .03 | 0.99 (0.99, 1.00) | | |
| | Known | 89 (62.7) | 333 (60.5) | | | | |
| | Unknown | 0 (0.0) | 5 (0.9) | | | | |
| Grand multiparity (≥3 live births) | Unknown | 0 (0) | 5 (0.9) | .04 | | Yes | Yes |
| | No | 111 (78.2) | 466 (84.7) | | 1.00 | | |
| | Yes | 31 (21.8) | 79 (14.4) | | 1.65 (1.04, 2.64) | | |
| Antenatal ultrasounds, No.* | 2 | 21 (14.8) | 120 (21.8) | .24 | 1.00 | | |
| | 1 | 46 (32.4) | 180 (32.7) | | 1.41 (0.80, 2.48) | | |
| | Unknown | 37 (26.1) | 125 (22.7) | | 1.64 (0.89, 2.98) | | |
| | 3 + | 38 (26.8) | 125 (22.7) | | 1.68 (0.94, 2.99) | | |
| Previous multiple delivery | Unknown | 8 (5.6) | 62 (11.3) | .06[§] | 0.41 (0.18, 0.93) | | |
| | No | 131 (92.3) | 483 (87.8) | | 1.00 | | |
| | Yes | 3 (2.1) | 5 (0.9) | | 1.82 (0.42, 7.84) | | |
| Vaginal bleeding* | Unknown | 41 (28.9) | 174 (31.6) | .16 | 0.94 (0.60, 1.45) | Yes | Yes |
| | No | 85 (59.9) | 341 (62.0) | | 1.00 | | |
| | Yes | 16 (11.3) | 35 (6.4) | | 1.89 (0.98, 3.62) | | |
| Booking[†,‡‡] | Yes | 109 (76.8) | 487 (88.5) | .003 | 1.00 | Yes | Yes |
| | No | 7 (4.9) | 15 (2.7) | | 2.19 (0.86, 5.56) | | |
| | Unknown | 26 (18.3) | 48 (8.7) | | 3.90 (1.96, 7.78) | | |
| High risk pregnancy[†] | No | 101 (71.1) | 473 (86.0) | <.001[¶] | 1.00 | | |
| | Yes | 13 (9.2) | 43 (7.8) | | 1.50 (0.77, 2.94) | | |
| | Unknown | 28 (19.7) | 34 (6.2) | | 4.35 (2.29, 7.91) | | |
| Antenatal care provider[†,§§] | GP/Ob/shared | 19 (13.4) | 135 (24.5) | <.001 | 1.00 | Yes | Yes |
| | Private midwife | 63 (44.4) | 253 (46.0) | | 1.91 (1.02, 3.57) | | |
| | Public | 46 (32.4) | 147 (26.7) | | 2.50 (1.34, 4.66) | | |
| | No care | 4 (2.8) | 6 (1.1) | | 4.84 (1.21, 19.35) | | |
| | Unknown | 10 (7.0) | 9 (1.6) | | 7.79 (2.73, 22.26) | | |
| Pregnancy medication variables | | | | | | | |
| Antihypertensives* | Unknown | 38 (26.8) | 195 (35.5) | .12 | 0.55 (0.33, 0.90) | | |
| | Yes | 5 (3.5) | 22 (4.0) | | 0.72 (0.26, 1.99) | | |
| | No | 99 (69.7) | 333 (60.5) | | 1.00 | | |
| Any* | No | 52 (36.6) | 270 (49.1) | .002 | 1.00 | Yes | |
| | Unknown | 27 (19.0) | 121 (22.0) | | 1.23 (0.72, 2.09) | | |
| | Yes | 63 (44.4) | 159 (28.9) | | 2.14 (1.39, 3.28) | | |
| Supplements[*,†,¶¶] | Yes | 19 (13.4) | 130 (23.6) | .02 | 1.00 | Yes | Yes |
| | No | 54 (38.0) | 188 (34.2) | | 2.01 (1.09, 3.69) | | |
| | Unknown | 69 (48.6) | 222 (40.4) | | 2.29 (1.22, 4.29 | | |
| Steroids* | Unknown | 38 (26.8) | 185 (33.6) | .002 | 0.73 (0.44, 1.21) | Yes | Yes |
| | No | 88 (62.0) | 346 (62.9) | | 1.00 | | |
| | Yes | 16 (11.3) | 19 (3.5) | | 3.54 (1.68, 7.45) | | |
| Antibiotics* | Unknown | 43 (30.3) | 208 (37.8) | <.001 | 0.96 (0.59, 1.58) | Yes | Yes |
| | Nil | 60 (42.3) | 290 (52.7) | | 1.00 | | |
| | UTI | 10 (7.0) | 21 (3.8) | | 2.94 (1.34, 6.45) | | |
| | STI | 10 (7.0) | 12 (2.2) | | 3.73 (1.53, 9.12) | | |
| | Other | 19 (13.4) | 19 (3.5) | | 4.29 (2.02, 9.12) | | |
| Delivery variables | | | | | | | |
| Duration 2[n†] stage, mean, minutes | | 32.13 | 46.34 | .02 | 0.99 | | |
| | Known | 92 (64.8) | 417 (75.8) | | | | |
| | Unknown | 50 (35.2) | 133 (24.2) | | | | |
| Fetal heart rate <100* | No | 78 (54.9) | 311 (56.5) | .84 | 1.00 | | |
| | Unknown | 40 (28.2) | 157 (28.5) | | 1.03 (0.61, 1.74) | | |
| | Yes | 24 (16.9) | 82 (14.9) | | 1.20 (0.70, 2.04) | | |
| Cord around neck | No | 104 (73.2) | 416 (75.6) | .79 | 1.00 | | |
| | Yes | 20 (14.1) | 75 (13.6) | | 1.06 (0.62, 1.82) | | |
| | Unknown | 18 (12.7) | 59 (10.7) | | 1.21 (0.68, 2.17) | | |

(*continued*)



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**Table II. Continued**

| Variables | Categories | Cases No. (%) | Controls No. (%) | *P* value | Univariable OR (95% CI) | Multivariable Step 1 | Multivariable Step 2 |
|---|---|---|---|---|---|---|---|
| Labor onset | Spontaneous | 90 (63.4) | 389 (70.7) | .35 | 0.81 (0.45, 1.49) | | |
| | Not in labor | 16 (11.3) | 58 (10.5) | | 1.00 | | |
| | Induced | 33 (23.2) | 95 (17.3) | | 1.24 (0.63, 2.42) | | |
| | Unknown | 3 (2.1) | 8 (1.5) | | 1.26 (0.28, 5.66) | | |
| Liquor volume* | Excessive | 1 (0.7) | 13 (2.4) | .27 | 0.33 (0.04, 2.53) | | |
| | Reduced | 4 (2.8) | 21 (3.8) | | 0.78 (0.26, 2.36) | | |
| | Normal | 81 (57.0) | 335 (60.9) | | 1.00 | | |
| | Unknown | 56 (39.4) | 181 (32.9) | | 1.33 (0.88, 2.01) | | |
| Fetal heart rate >160* | No | 89 (62.7) | 357 (64.9) | .77 | 1.00 | | |
| | Unknown | 44 (31.0) | 166 (30.2) | | 1.10 (0.66, 1.84) | | |
| | Yes | 9 (6.3) | 27 (4.9) | | 1.34 (0.59, 3.02) | | |
| Operative or instrumental | No | 85 (59.9) | 372 (67.6) | .22 | 1.00 | | |
| | Unknown | 3 (2.1) | 10 (1.8) | | 1.29 (0.34, 4.88) | | |
| | Yes | 54 (38.0) | 168 (30.5) | | 1.42 (0.97, 2.09) | | |
| Fetal distress | No | 87 (61.3) | 378 (68.7) | .23 | 1.00 | | |
| | Unknown | 16 (11.3) | 46 (8.4) | | 1.38 (0.88, 2.17) | | |
| | Yes | 39 (27.5) | 126 (22.9) | | 1.48 (0.79, 2.78) | | |
| Meconium | Yes | 27 (19.0) | 113 (20.5) | .37 | 0.95 (0.59, 1.52) | | |
| | No | 101 (71.1) | 402 (73.1) | | 1.00 | | |
| | Unknown | 14 (9.9) | 35 (6.4) | | 1.62 (0.82, 3.21) | | |
| Membrane rupture >48 h | No | 108 (76.1) | 503 (91.5) | <.001 | 1.00 | Yes | Yes |
| | Unknown | 22 (15.5) | 36 (6.5) | | 3.31 (1.72, 6.37) | | |
| | Yes | 12 (8.5) | 11 (2.0) | | 6.32 (2.42, 16.48) | | |
| Child variables | | | | | | | |
| Apgar 5 min, mean | | 9.26 | 9.56 | <.001 | 0.71 (0.58, 0.87) | | |
| | Known | 137 | 549 (0.0) | | | | |
| | Unknown | 5 (3.5) | 1 (0.2) | | | | |
| Apgar 1 min, mean | | 8.01 | 8.44 | .001 | 0.82 (0.72, 0.93) | | |
| | Known | 137 | 549 (0.0) | | | | |
| | Unknown | 5 (3.5) | 1 (0.2) | | | | |
| Weight, z score, mean | | 0.06 | 0.28 | .06 | 0.85 (0.72, 1.00) | Yes | |
| | Known | 139 | 547 (0.0) | | | | |
| | Unknown | 3 (2.1) | 3 (0.5) | | | | |
| Length of stay, mean, d | | 10.18 | 4.04 | <.001 | 1.09 (1.06, 1.13) | Yes | |
| | Known | 136 | 543 (0.0) | | | | |
| | Unknown | 6 (4.2) | 7 (1.3) | | | | |
| Vitamin K | No | 2 (1.4) | 10 (1.8) | .01 | 1.00 | Yes | |
| | Yes | 134 (94.4) | 537 (97.6) | | 1.25 (0.27, 5.71) | | |
| | Unknown | 6 (4.2) | 3 (0.5) | | | | |
| Resuscitation method | Unknown | 7 (4.9) | 56 (10.2) | .001 | 0.51 (0.22, 1.19) | Yes | |
| | No | 85 (59.9) | 376 (68.4) | | 1.00 | | |
| | Oxygen only | 17 (12.0) | 56 (10.2) | | 1.47 (0.79, 2.70) | | |
| | O2 and bag | 33 (23.2) | 62 (11.3) | | 2.60 (1.55, 4.37) | | |
| Sex | Female | 55 (38.7) | 260 (47.3) | .07 | 1.00 | Yes | |
| | Male | 87 (61.3) | 290 (52.7) | | 1.39 (0.97, 2.01) | | |
| Alternative postnatal facility | Yes | 14 (9.9) | 135 (24.5) | <.001 | 1.00 | Yes | Yes |
| | No | 126 (88.7) | 412 (74.9) | | 3.27 (1.78, 6.01) | | |
| | Unknown | 2 (1.4) | 3 (0.5) | | | | |
| Special care baby unit | No | 93 (65.5) | 492 (89.5) | <.001 | 1.00 | Yes | |
| | Yes | 46 (32.4) | 55 (10.0) | | 4.99 (3.04, 8.19) | | |
| | Unknown | 3 (2.1) | 3 (0.5) | | | | |
| Preterm (<37/40) | No | 100 (70.4) | 507 (92.2) | <.001 | 1.00 | Yes | |
| | Yes | 42 (29.6) | 43 (7.8) | | 5.78 (3.38, 9.87) | | |
| Birth type | Singleton | 126 (88.7) | 537 (97.6) | <.001 | 1.00 | Yes | |
| | Twin | 16 (11.3) | 13 (2.4) | | 7.27 (2.95, 17.91) | | |
| Exclusive breastfeeding | Yes | 49 (34.5) | 358 (65.1) | <.001 | 1.00 | | |
| | No | 74 (52.1) | 164 (29.8) | | 4.18 (2.66, 6.58) | | |
| | Unknown | 19 (13.4) | 28 (5.1) | | 7.46 (3.52, 15.82) | | |
| Type of feeding at discharge*** | Breastmilk | 65 (45.8) | 432 (78.5) | <.001 | 1.00 | Yes | Yes |
| | Both | 31 (21.8) | 59 (10.7) | | 3.89 (2.24, 6.76) | | |
| | Formula | 36 (25.4) | 49 (8.9) | | 6.15 (3.49, 10.84) | | |
| | Unknown | 10 (7.0) | 10 (1.8) | | 9.90 (3.45, 28.45) | | |
| Gestation, mean, wk | | 37 | 39 | <.001 | 0.71 (0.65, 0.78) | Yes | Yes |

(*continued*)



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**Table II. Continued**

| Variables | Categories | Cases No. (%) | Controls No. (%) | *P* value | Univariable OR (95% CI) | Multivariable Step 1 | Multivariable Step 2 |
|---|---|---|---|---|---|---|---|
| Referral for social support or intervention variables | | | | | | | |
| To hospital social worker | No | 98 (69.0) | 515 (93.6) | <.001 | 1.00 | Yes | Yes |
| | Yes | 38 (26.8) | 32 (5.8) | | 6.15 (3.59, 10.55) | | |
| | Unknown | 6 (4.2) | 3 (0.5) | | 12.93 (2.45, 68.23) | | |
| To child protective services | No | 122 (85.9) | 539 (98.0) | <.001 | 1.00 | Yes | |
| | Yes | 12 (8.5) | 8 (1.5) | | 7.81 (2.88, 21.13) | | |
| | Unknown | 8 (5.6) | 3 (0.5) | | 17.24 (3.41, 87.24) | | |
| To police | No | 131 (92.3) | 547 (99.5) | <.001 | 1.00 | | |
| | Unknown | 10 (7.0) | 3 (0.5) | | 17.87 (3.88, 82.41) | | |
| | Yes | 1 (0.7) | 0 (0.0) | | >999 (<.01, >999) | | |
| To community support | No | 107 (75.4) | 512 (93.1) | <.001 | 1.00 | Yes | |
| | Yes | 24 (16.9) | 36 (6.5) | | 3.29 (1.84, 5.87) | | |
| | Unknown | 11 (7.7) | 2 (0.4) | | 47.58 (6.04) | | |

*UTI,* urinary tract infection; *STI,* sexually transmitted infection.
Step 1 is group multivariable analysis; Step 2 is combined multivariable analysis.
*More than 20% of data were unknown.
†Unknown was associated with risk.
‡New Zealand Deprivation Index. From address and 9 census variables (receiving a means-tested benefit, living in a household below an equivalized income threshold, not living in own home, single parent family, unemployed, no qualification obtained from a completed course of at least 3 months of full time study, living in a household below an equivalized bedroom occupancy threshold, with no access to a telephone, with no access to a car).
§Ethnicity. Participant-defined. If multiple, prioritized as Māori, Pacific, Asian, Other, European.
¶De facto. Living together as a couple but not married.
**Other social history. Any social concern documented in clinical notes. Examples: attempted suicide, child in care, child protective services involved, partner in jail, prostitution, single parent, social worker involved.
††Substance abuse. Any documented use of drug or alcohol services.
‡‡Booking. Whether the mother registered for antenatal care at any time prior to delivery.
§§Antenatal care provider. All care from GP, all care from private Ob, shared antenatal care with GP but hospital managed delivery and postnatal care (shared), all care from private midwife, all care from hospital (public).
¶¶Supplements. Any medication not usually prescribed e.g. folate, vitamins, iron (if not prescribed for anemia).
***Type of feeding at discharge. Pattern in 24 hours before discharge. Breast includes expressing.



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