PAIN RELIEF IN LABOR BY TRANSCUTANEOUS ELECTRICAL NERVE STIMULATION

Testing of a modified stimulation technique and evaluation of the neurological and biochemical condition of the newborn infant

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Abstract. In this prospective randomized study of pain relief in labor, the effect of transcutaneous electrical nerve stimulation (TNS) performed over both the low-back and suprapubic region was evaluated and compared with a control group not receiving TNS. Both high frequency and pulse train TNS were used. The study included 24 induced labors. In the TNS group, conventional methods were added when needed, while in the control group only conventional methods were used. Assessment of low-back and suprapubic pain was performed by the parturient each hour during the first stage. In the TNS group most of the parturients reported minimal or moderate low-back pain throughout labor, while parturients in the control group reported an increased intensity of low-back pain as labor progressed. The effect on suprapubic pain was insignificant in both groups. Neither TNS nor nitrous oxide-oxygen mixture and pethidine could reduce this pain component. Course of labor, uterine activity and fetal heart patterns were similar in the two groups. The neonates were evaluated with Apgar score, assays of blood samples from the umbilical vein including blood lactate, plasma hypoxanthine and blood gas, and neurobehavioral assessment on two occasions. All newborn infants were in good condition and no significant differences between the two groups could be demonstrated.

Several studies concerning transcutaneous electrical nerve stimulation (TNS) for pain relief during labor have been published recently (2, 4, 6, 7, 17, 21, 24, 27, 29, 31). No adverse effects on the mother or newborn infant, as judged by the routinely used monitoring techniques, have been reported. However, the lack of reported side effects on infants stems from clinical evaluation of the fetus and neonate including the use of Apgar score, while more elaborate methods for the investigation of fetal and neonatal well-being have not been used. In all the studies TNS was found to have an analgesic effect and some authors considered it comparable to pethidine (5, 21). Other authors concluded that TNS had a good effect on the low-back pain, whereas the suprapubic pain was not alleviated by this stimulation technique (7, 24, 27). The finding that TNS had a specific effect on the low-back pain focused interest on pain location and the effect of conventional analgesic methods used in the first stage of labor. Two recent studies at this department demonstrated that few women experienced good relief of both low-back and anterior pain when pethidine and/or nitrous oxide-oxygen mixture were used (7, 8).

To improve the effect of TNS, we suggested that stimulation should also be given over the lower abdomen in order to reduce anterior pain (7). Robson (24) tested suprapubic stimulation in 2 patients. Both derived great relief from this treatment. However, it cannot be excluded that suprapubic stimulation with conventional electrodes might induce irregularities in the fetal heart rate during unfavorable conditions owing to high current density close to the fetal heart. The current density due to suprapubic stimulation was therefore analyzed and safety criteria proposed (9, 11). A special apparatus fulfilling these criteria was tested clinically and no side effects on the mother or child were found (9).

The aim of this study was to evaluate the effect of dorsal and suprapubic TNS at two different frequencies (cf. 12, 13) during labor and compare the effect with conventional methods of pain relief. The study also comprises an elaborate evaluation of the condition of the newborn infant, including biochemical tests and detailed neurological examination.

PATIENTS AND METHODS

Selection of patients. The study was performed during a 2-month period in 1979. All women attended the antenatal clinic during pregnancy. In order to have as uniform an in-
vestigation group as possible, only induced labors were included. This means that the whole labor, from the first uterine contraction to parturition, could be observed. Induction was only performed if the parturient’s cervix was ripe, judged by the modified Bishop score (1). A senior obstetrician assessed the state of the cervix and thereafter decided on induction of labor. The most common indication for induction was post-term pregnancy (TNS group 11, control group 6). The second most common indication was pre-eclampsia (TNS group 2, control group 1). In addition, labor was induced because of suspected intrauterine growth retardation in one parturient in each group and for psychosocial reasons in one in each group. Only Swedish-speaking women with the fetus in the vertex position were included.

Standardized verbal and written information concerning the study and the available methods of pain relief was given to the parturients by one of the authors (P. B.). Women who were primarily biased for or against a certain method of pain relief were not included in the study. With the patient’s consent, she was randomly assigned to either the TNS group or the control group. The only requirement of women assigned to the TNS group was that they had to test the effect of TNS before being offered other methods of pain relief. If a parturient had to be delivered by cesarean section, she was omitted from the study.

**Intrapartal monitoring and management.** Labor was induced at term by primary amniotomy and supervised by electronic monitoring (Corometrics®). The fetal heart rate was registered by means of a scalp electrode and the uterine activity by means of an open-end intrauterine catheter. The uterine activity was quantified by calculating the Monte Carlo curve. At the same time, the women answered two written questions concerning the intensity of low-back pain and abdominal pain, according to a five-point scale — ranging from ‘no pain’ to ‘almost unbearable pain’. When the contractions became painful, pain relief was given according to the conditions of this study. All obstetric analgesia was registered, as were changes in the rate of oxytocin infusion. On the first day after delivery the women answered a questionnaire concerning location and experience of pain in different phases of labor and the effect of pain relief given.

**Evaluation of analgesic effect.** At one-hour intervals after amniotomy the cervical dilatation was checked by the midwife and registered on the partogram and the cardiographic curve. At the same time, the women answered two written questions concerning the intensity of low-back pain and abdominal pain, according to a five-point scale — ranging from ‘no pain’ to ‘almost unbearable pain’. When the contractions became painful, pain relief was given according to the conditions of this study. All obstetric analgesia was registered, as were changes in the rate of oxytocin infusion. On the first day after delivery the women answered a questionnaire concerning location and experience of pain in different phases of labor and the effect of pain relief given.

**Evaluation of the fetal and neonatal condition.** The fetal heart rate patterns were classified according to Hon (15) and Hammacher et al. (14). The time from delivery, i.e. when the whole baby was delivered, to first cry or breath was noted. The Apgar scores at one and five minutes were recorded. At 60 sec the umbilical cord was double-clamped and blood samples were drawn anaerobically from the vein by one of us (P. B.). The sample for blood-gas analysis was taken in a heparinized glass syringe and transported on ice to the laboratory for immediate analysis. Oxygen saturation (SO₂) and hemoglobin concentration were measured using a filter photometer (Radiometer OSM 2). Blood-gas tensions and pH were measured at 38°C with a Radiometer BMS 3, using standard electrodes. Base excess (BE) values were calculated from the Siggaard-Andersen nomogram at the prevailing hemoglobin concentration. Blood-lactate levels were measured by an enzymatic method (Boehringer Mannheim). Plasma hypoxanthine concentrations were determined using a pO₂ electrode to measure the rate of oxygen consumption after the addition of xanthine oxidase according to a method described by Saugstad (25).

The newborn infants were evaluated on two occasions by the pediatrician participating in the study (K. T.) without knowledge of the group to which the newborn infants belonged. The first examination was carried out in the delivery room 30–120 min after parturition. Besides a detailed physical examination, the evaluation of the infant included state of alertness, reflexes, muscle tone and excitability. The scoring also included the facial expression (drowsy, calm, satisfied, alert, worried, irritable or disconsolate crying) and the ability to follow a bright object (a yellow ball).

A more detailed neurological examination was performed at the age of 10–19 hours. This evaluation included 30

Table I. Baseline variables.

<table>
<thead>
<tr>
<th></th>
<th>TNS group (n = 15)</th>
<th>Control group (n = 9)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mothers</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>28±5</td>
<td>26±4</td>
</tr>
<tr>
<td>Primiparae</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Multiparae</td>
<td>10</td>
<td>6</td>
</tr>
<tr>
<td><strong>Newborns</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gestational age</td>
<td>41±1</td>
<td>41±1</td>
</tr>
<tr>
<td>Birth weight (g)</td>
<td>3600±460</td>
<td>3620±370</td>
</tr>
<tr>
<td>Percentual weight loss (%)</td>
<td>6.5±1.7</td>
<td>7.0±2.1</td>
</tr>
<tr>
<td>Apgar score 1 min</td>
<td>9.5</td>
<td>9.6</td>
</tr>
<tr>
<td>5 min</td>
<td>10.0</td>
<td>9.9</td>
</tr>
</tbody>
</table>

RESULTS

Baseline variables. One parturient in each group was delivered by cesarean section for reasons apparently not related to pain relief given, and were excluded. Of the remaining 26 parturients — 16 in the TNS group and 10 in the control group — who entered the study, one in each group received EDA owing to lack of effect of the other methods used. These 2 patients were excluded due to the special problems associated with parturients having EDA (8, 22, 26, 33).

Pain location was similar in the two groups. The distribution between primiparae and multiparae was equal (Table I). In the newborn infants, gestational age, birth weight, percentage weight loss and Apgar scores were similar (Table I).

Table II. Modified Bishop score and cervical dilatation at amniotomy related to time course of labor.

<table>
<thead>
<tr>
<th></th>
<th>TNS group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modified Bishop score</td>
<td>6.3±1.6</td>
<td>7.6±1.5</td>
</tr>
<tr>
<td>Cervical dilatation at amniotomy (cm)</td>
<td>2.1±0.4</td>
<td>2.9±0.8</td>
</tr>
<tr>
<td>Onset of labor — 5 cm dilatation (h)</td>
<td>3.4±1.4</td>
<td>2.6±1.3</td>
</tr>
<tr>
<td>5—10 cm dilatation (h)</td>
<td>1.4±0.8</td>
<td>1.6±1.2</td>
</tr>
<tr>
<td>10 cm — parturition (h)</td>
<td>0.9±0.8</td>
<td>1.1±1.1</td>
</tr>
<tr>
<td>Total duration of labor (h)</td>
<td>5.6±2.4</td>
<td>5.3±2.6</td>
</tr>
</tbody>
</table>

Course of labor. In Table II the modified Bishop score, cervical dilatation at amniotomy and the duration of the different stages of labor are presented. Although the parturients in the control group had a somewhat more favorable condition of the cervix and a quicker dilatation to 5 cm, the time from 5 to 10 cm and from 10 cm to parturition was somewhat shorter in the TNS group, though showing no statistical significance. The interval from 5 cm to parturition was 2.3±1.5 hours in the TNS group compared with 2.7±2.3 hours in the control group. The mean values for uterine activity as measured by both Montevideo units and area below the pressure curve were somewhat higher in the TNS group than in the control group (Table III), but the differences showed no statistical significance.

One post-term primipara in each group was delivered by vacuum extraction. The other parturients gave birth spontaneously — one multipara in the control group with the fetus in occipito-posterior position and the remainder with fetuses in the occipito-anterior position.

Fetal condition during labor. The fetal heart rate patterns were analyzed visually with respect to basal heart rate, deceleration patterns and long-term variability. No attempt to analyze short-term variability was made. The analysis showed no differences between the groups concerning basal heart rate and decelerations, and no specific effect due to TNS treatment could be discerned. The interpretation of long-term variability was complicated by the fact that many parturients in both groups received pethidine. However, in 2 patients receiving pulse-train TNS and in one patient with high-frequency TNS, a reduced long-term variability was apparent both before and during the TNS treatment.

Pain relief, first stage. The majority of parturients in the TNS group were given TNS over the low-back region before suprapubic TNS was started, in accordance with the appearance of pain (Fig. 1). From amniotomy the cervix dilated on average 1.3 cm before low-back TNS (15 cases) was given and 2.1 cm before suprapubic TNS (13 cases) was given. In the TNS group pethidine (12 cases) was given when cervix had dilated on average 2.4 cm from amniotomy and N_2O/O_2 (9 cases) when cervix had dilated on average 3.2 cm from amniotomy. One multipara in the TNS group received PCB at a cervical dilatation of 6 cm. She wanted low-back and suprapubic stimulation to be continued after being given the blockade.

In the control group the cervix dilated on average 1.2 cm from amniotomy before N_2O/O_2 was given (9 cases) and on average 1.5 cm before pethidine was given (8 cases). One multipara in the control group received PCB at a cervical dilatation of 4 cm.

Intrapartal assessment of low-back and suprapubic pain was performed each hour during the first stage. In 9 parturients in the TNS group and in 4 in the control group the cervix dilated from 5 to 10 cm within 1 hour, which resulted in few answers in the late first stage (Table IV). Six parturients were randomized to start with pulse-train TNS and 3 of these experienced good relief of low-back pain, while one more parturient experienced good relief after changing from pulse-train to high-frequency TNS. Nine parturients started with high frequency TNS. Among these, 5 experienced good relief of low-back pain and thereafter one more parturient after changing to pulse-train TNS. Twelve patients in the TNS group experienced minimal or moderate low-back pain at a cervical dilatation of 4 – 5 cm. Seven of them reported unchanged or reduced pain at 6 – 10 cm, while 5 had no time to answer due to rapid cervical dilatation. In the control group 4 patients had minimal or moderate pain at 4 – 5 cm and all reported severe to almost unbearable pain the the late first stage (Table IV). The majority of parturients in both the TNS and control group experienced severe suprapubic pain at the time when pethidine was given. The suprapubic pain was not affected by either TNS or N_2O/O_2 and/or pethidine.

Pain relief, second stage. Pudendal block was given to 13 parturients in the TNS group and 7 in the control group. Eight parturients in the TNS group and none in the control group experienced good relief of pain in the second stage. Five parturients in the TNS group graded their total pain as only minimal or moderate in the second stage, compared with none in the control group. This supports the observation that TNS reduces pain also in the second stage.

Evaluation of the infants. All newborns were delivered in good condition and clinical signs of extrauterine asphyxia were not present in any infant. The time from delivery to first cry or breath did not exceed 30 sec in any case and Apgar scores (Table I) were similar in both groups. The mean values for umbilical vein pH, blood gases, oxygen saturation, lactate and

Table IV. Location and intensity of pain in relation to cervical dilatation.

<table>
<thead>
<tr>
<th>TNS Group</th>
<th>Control</th>
<th>TNS Group</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amniotomy</td>
<td>Low-back TNS (15)</td>
<td>Suprapubic TNS (13)</td>
<td>Pethidine (12)</td>
</tr>
<tr>
<td>cm 21</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>cm 21</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Amniotomy</td>
<td>N_2O/O_2 (9)</td>
<td>Pethidine (8)</td>
<td></td>
</tr>
<tr>
<td>cm 29</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>cm 29</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
</tbody>
</table>

Fig. 1. Instigation of different analgesic methods in relation to cervical dilatation at amniotomy.

hypoaxanthine are given in Table V. The mean values showed no deviations from values usually found after normal births (18), and were similar in the TNS and control group. Although the hypoaxanthine levels in the TNS infants were more widely scattered, with a greater range (0–16.8 μmol/l) than in the control group (0–9.8 μmol/l), the difference was not significant when tested by the Wilcoxon rank-sum test.

The scores attained in the neurological examinations of the infants are summarized in Table VI. The examinations did not reveal any disturbances attributable to TNS. The mean scores and score ranges were comparable for the two groups of infants. In the more detailed second examination the infants demonstrated no major neurological deviations apart from one infant in each group with evident irritability. This was attributed to the fact that they were delivered by vacuum extraction. No significant differences could be found in muscular tone, excitability, number of optimum items or total neurological score, though there was a slight tendency towards more normal values for all variables in the TNS group. Optimum excitability and tone scores (14 + 1) could be demonstrated in 9 and 11 respectively of the 13 infants examined in the TNS group, while in the control group 4 of the 8 infants studied were given optimum scores. The newborn infants in the TNS group achieved 22.6 optimum items, compared with 21.6 in the control group.

**DISCUSSION**

In this study a modified technique for TNS for pain relief during labor was tested. A specially designed current-controlled stimulator was used. It was possible to test both pulse train and high-frequency TNS and to stimulate suprapubically with an electrode fulfilling the safety criteria proposed in an earlier study (9).

Only induced labors were included. Although the modified Bishop score and the degree of cervical dilatation at amniotomy were lower in the TNS group than in the control group, no significant differences were noted in the time course of labor. Rather, there was a slight tendency in the TNS group toward increased uterine activity, as measured in Montevideo Units and area below the pressure curve. This is in agreement with Kubista et al. (17), who concluded in their study that apart from the good analgesic effect obtained, an advantage of TNS was the quick course of labor.

The analysis of the fetal heart rate patterns disclosed no significant differences. The interpretation of long-term variability was, however, complicated by the fact that many parturients in both groups received pethidine.

The previously documented good effect of TNS on low-back pain (7) was confirmed in this study. This pain-reducing effect of TNS was maintained through-

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**Table V. Blood samples taken from the double-clamped umbilical vein (Mean±SD).**

<table>
<thead>
<tr>
<th></th>
<th>TNS group</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.35±0.06</td>
<td>7.36±0.08</td>
</tr>
<tr>
<td>pCO2 (kPa)</td>
<td>4.6±0.9</td>
<td>4.1±0.6</td>
</tr>
<tr>
<td>pO2 (kPa)</td>
<td>5.0±0.7</td>
<td>5.7±0.5</td>
</tr>
<tr>
<td>SO2 (%)</td>
<td>63±13</td>
<td>67±13</td>
</tr>
<tr>
<td>BD (mmol/l)</td>
<td>6.0±0.3</td>
<td>7.2±3.5</td>
</tr>
<tr>
<td>Lactate (mmol/l)</td>
<td>2.7±0.9</td>
<td>3.0±1.9</td>
</tr>
<tr>
<td>Hypoxanthine (μmol/l)</td>
<td>6.3±6.5</td>
<td>2.4±3.6</td>
</tr>
</tbody>
</table>

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**Table VI. Examination of the newborns.**

<table>
<thead>
<tr>
<th></th>
<th>TNS (n = 14)</th>
<th>Controls (n = 8)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>First examination (max 11)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Range</td>
<td>9.3±1.5</td>
<td>8.6±2.1</td>
</tr>
<tr>
<td>Infants with score ≥10</td>
<td>6.5–11</td>
<td>5–11</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td><strong>Second examination</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tonus score (optimal = 14, range 8–30)</td>
<td>13.9±1.1</td>
<td>15.4±2.0</td>
</tr>
<tr>
<td>Infants with score 14±1</td>
<td>11</td>
<td>4</td>
</tr>
<tr>
<td>Excitability score (optimal = 14, range 9–33)</td>
<td>14.7±1.3</td>
<td>14.8±2.4</td>
</tr>
<tr>
<td>Infants with score 14±1</td>
<td>9</td>
<td>4</td>
</tr>
<tr>
<td>Total number of optimal items (max 27)</td>
<td>22.6±2.3</td>
<td>21.6±4.5</td>
</tr>
</tbody>
</table>

out labor. The parturients did not report any alterations in pain intensity of the low-back pain during the first stage. Although pudendal block was used equally often in both groups, while nitrous oxide-oxygen mixture was used less often in the TNS group than in the control group, relief of pain was better and pain intensity lower in the TNS group in the second stage. It is suggested that the high incidence of good pain relief is due to the TNS treatment. The study indicated that parturients who failed to experience relief of low-back pain with high-frequency TNS could be helped by pulse-train TNS, and vice versa. This is in keeping with studies performed during other conditions (12, 13, 20).

In the first stage no obvious effect on suprapubic pain was observed in either TNS or control group. Thus, neither TNS nor N₂O/O₂ and/or pethidine could reduce this pain component. A question that arises is whether the suprapubic pain in the first stage is resistant to TNS. This question cannot be answered on the basis of experience from this study. The suprapubic pain is undoubtedly more intense and well defined than the diffuse low-back pain. This indicates indirectly that the suprapubic pain is mediated mainly via A delta fibres, while the low-back pain is mediated via C fibres. Experience from TNS treatment in other conditions indicates that the best effect is usually obtained in C-fibre-mediated pain (3). It should be pointed out that the suprapubic electrode was designed to give high current density in the vicinity of the electrode, while deeper structures would receive minimal current.

Experience from TNS treatment in other painful conditions indicates that optimal pain relief is obtained when both skin and muscle afferents are activated (3). During pulse-train TNS, activation of muscle afferents seems to be of major importance (28). It is therefore possible that the pain-reducing effect of suprapubic TNS can be enhanced if stimulation is also allowed to activate muscle afferents. Further safety studies will probably show that the proposed preliminary current density standard for the fetal heart (9) is too low and can be raised without jeopardizing safety.

Since it cannot be excluded that suprapubic stimulation might induce irregularities in the fetal heart rate in unfavorable cases, the need for meticulous fetal monitoring and thorough evaluation of the newborn infant is obvious in a study of this kind. We are not aware of any reports concerning the condition of the newborn infant after TNS in labor as assessed by methods other than the Apgar score. Recent studies on newborn infants have indicated that neurobehavioral evaluation gives more adequate information on neonatal condition than does the routinely used Apgar score (18, 22, 26).

No infant in this study developed extrauterine asphyxia, as measured by Apgar score. The mean umbilical vein pH was similar in the two groups and did not differ from values usually found after normal deliveries (16) or after induced labor (18). Mean values for pCO₂, pO₂, SO₂ and BE were also in accordance with normal values found in umbilical blood and no significant differences were noted between the TNS and control group. All infants except one baby in the control group had lactate values below 4 mmol/l.

Hypoxanthine is a degradation product of energy-rich cell purines (ATP and ADP) and has recently been claimed to reflect tissue hypoxia in a specific and sensitive way (25). During graded asphyxia in the fetal lamb the concentration of hypoxanthine in fetal plasma showed a close correlation to other indices of hypoxia (32). Only a few small clinical materials of newborns have so far been published on this topic (19, 25, 30). In infants with pH values above 7.18 Lipp et al. found values between 6 and 28 µmol/l, while Saugstad measured values between 11 and 61.5 µmol/l in association with signs of perinatal asphyxia. In another group of neonates with Apgar scores exceeding 7, a value of 12.2±7.2 was measured in arterial plasma at an age of 10 min (30). Our values are of the same magnitude as these measurements and confirm, additionally, the absence of perinatal asphyxia.

The neurological examinations of the infants born after TNS and after conventionally used pain relief also failed to demonstrate any significant differences between the groups. The neurological scores achieved by the infants at the second examination are close to the scores Leijon et al. found after induced deliveries and normal births when they used the same scoring system (18). Our infants scored somewhat lower for optimum items, which we believe to be due to interobserver difference. The tendency towards slightly more frequent 'normal' and 'optimum' scoring in the TNS group might be the result of the less frequent use of the nitrous oxide-oxygen mixture in this group.

It can thus be concluded that no adverse effect of TNS is demonstrable by clinical, laboratory or neurological examination of the infants after pain relief by TNS.

APPENDIX

Grouping of items in the neurological examination.
Figures in parenthesis are possible scores

Items measuring muscular tonus (8–30)
- Spontaneous posture supine position (1–3)
- Resistance against passive movements, body and neck (1–4)
- Resistance against passive movements, arms (1–4)
- Resistance against passive movements, legs (1–4)
- Recoil, arms (1–4)
- Traction response, arms (1–4)
- Traction response, head (1–4)
- Head control, vertical position (1–3)

Items measuring excitability (9–33)
- Optic blink reflex (1–3)
- Acoustic blink reflex (1–3)
- Patellar reflex (1–4)
- Withdrawal reflex (1–3)
- Rooting reflex (1–4)
- Ability to suck (1–4)
- Palmar grasp (1–4)
- Spontaneous motility (1–4)

Optimal items (items where optimal response is possible to state)
- The items measuring muscular tonus (see above)
- The items measuring excitability (see above)
- Moro tremor excluded
- Face expression (1–2)
- Cry (1–4)
- Symmetry in body position (1–2)
- Eyes following a yellow ball (1–3)
- Doll’s eye test (1–2)
- Pupil’s reaction to light (1–3)
- Glabellar reflex (1–2)
- Moro reflex (1–4)
- Crawling (1–4)
- Placing response (1–2)
- Automatic walking (1–3)

ACKNOWLEDGEMENTS

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