BIODYNAMICS OF THE CERVICAL DILATATION IN HUMAN LABOR

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Synopsis

We recorded the pressure between the fetus and birth canal (PFB) with small strain-gauge type pressure transducers in 37 cases of human labor and estimated expulsive activity for evaluation of the expulsive forces. Expulsive activity increased progressively in conjunction with cervical dilatation and markedly increased after rupture of the membranes. At less than 200 Hashimoto units of expulsive activity, the cervical canal could not be dilated and labor was prolonged in all periods of the first stage of labor. There were three types of modes of changes in the expulsive activities at three points on the cervical canal. These three types had different clinical characteristics of cervical dilatation during labor. New parameters such as the expulsive effort, efficiency index and resistance index of the uterine cervix, estimated together with the expulsive activity, were proposed in an attempt to evaluate the effect of expulsive forces on cervical dilatation.

Key words: Cervix uteri • Dilatation • Fetus • Labor • Uterine contraction

Introduction

It is certain that uterine contractions dilate the cervical canal and cause the fetus to descend during labor. To estimate the uterine expulsive forces, the uterine activity has been calculated from changes in amniotic pressure and expressed in Montevideo units⁵ or uterine activity units⁶. However, no method has been established to evaluate the uterine expulsive forces more accurately. Since the uterine activity indicates uterine contractility only, and the expulsive activity⁵⁻⁶ in this report is calculated from changes in pressure between the fetus and birth canal (hereafter abbreviated as PFB), it may lead to the estimation of expulsive forces themselves. The cumulative value of expulsive activity, expressed as expulsive effort, may indicate the total action of expulsive forces in a certain period during labor. Using the expulsive effort value, we tried to establish a method for the quantitative estimation of the cervix dilating effect caused by uterine contractions.

Materials and Methods

PFB were recorded in 37 cases in labor (25 cases of primiparae and 12 cases of multi-parae). These cases were all of the cephalic presentation at term without complications. Most of them were spontaneous labor but some were labor induced with oxytocin, prostaglandin F₂₄ or prostaglandin E₂.

The sensor (PS-2K, Kyowa Electronic Instrument Company) to estimate PFB was a pressure transducer of the strain-gauge type in the form of a thin disk (0.6 mm in thickness) 6 mm in diameter. These sensors were arranged longitudinally at intervals of 2.5 cm on a thin plastic plate which was covered with water-proof latex and sterilized (Fig. 1). The plate was inserted at the side of the fetal occiput in the contact space between the fetus and cervical canal, and fixed on the cervical lip with forceps (Fig. 2). At this time, the three sensors should be located ① 9.5 cm, ② 7.0 cm and ③ 4.5 cm respectively from the external uterine orifice. The electrical activities of the sensors were amplified with dynamic strain amplifier (DPM-110, Kyowa Electronic Instrument Company) and recorded with a multi-channel recorder (WA 331, Watanabe Instrument Corporation) at a paper speed of 2.5 cm/min. The zero level was defined as the unloaded pressure in the atomosphere.
For the estimation of amniotic pressure, a thin polyethylene catheter filled with saline was inserted into the intra-amniotic cavity and connected to a pressure transducer (MPU-0.5, Nihon Kohden) of the strain-gauge type.

Recorded curves of both PFB and amniotic pressure were slow waves corresponding to the uterine contractions (Fig. 3). The curves were analyzed as follows. The tonus was the pressure when the uterus was relaxed. The intensity was the increase in the pressure caused by uterine contraction. The frequency was the number of the uterine contractions in ten minutes.

**Results**

1. **Pressure between the fetus and birth canal (PFB)**

The PFB increased gradually in the first stage of labor (Fig. 4). The levels of pressure $1$, recorded in the innermost part on the cervical canal, decreased slightly and those at the points $2$ and $3$ increased progressively in conjunction with cervical dilatation. When the highest level of PFB among the three parts of the cervical canal were observed, this was increasing in the first stage of labor as shown in Table 1.

In the first stage of labor, the tonus of PFB showed hardly any change, the intensity, however, increased markedly except at cervical diameters of 8–9 cm in cases with the intact membranes and frequency increased up to 4–5/ten minutes in the latter half of cervical dilatation.
Even after rupture of the membranes, tonus showed little change and frequency increased slightly, but intensity showed continuous increase, especially when rupture of the membranes occurred at cervical diameters of 5–7 cm, its increase was remarkable.

Changes in the level of PFB and amniotic pressure were synchronized with the uterine contractions. The PFB (Y) were 2.2–3.4 times as high as the amniotic pressure (X) through the first stage of labor. The regression equation was \( Y = 26.85 + 2.31X \) and the coefficient of correlation was 0.64. The correlation between X and Y was significant (\( p < 0.001 \)).

2. Expulsive activity

The expulsive activity is the product of the intensity of PFB multiplied by the frequency of uterine contractions. This value is expressed in "Hashimoto units". The regression equation of the correlation between expulsive activity (Y) and uterine activity (X) was \( Y = 4.10 + 2.96X \) and the coefficient of correlation was 0.64. The correlation between X and Y was significant (\( p < 0.001 \)).

Expulsive activity increased progressively in conjunction with cervical dilatation, and it markedly increased after rupture of the membranes and after cervical diameter of 7 cm in primiparae. The average values of expulsive activity were 300–400 Hashimoto units in the first half of cervical dilatation and 600 Hashimoto units at full dilatation. At less than 200 Hashimoto units of expulsive activity, the cervical canal was not dilated and labor was prolonged in all periods of the first stage of labor. When the uterine contractions were stimulated with oxytocin or prostaglandin, the expulsive activity was increased rapidly.

The expulsive activities estimated at three points on the cervical canal changed depending on the cervical dilatation. There were three types of modes of changes. In type I, the expulsive activity in the innermost part (1) of the cervical canal was always higher than those at (2) or (3) near the external os of the cervical canal (Fig. 5). In type II, the expulsive activity at (2) or (3) was always higher than that at (1) (Fig. 6). In type III, the mode of changes in the expulsive activities showed the same changes as type I in the early stage of cervical dilatation, but at cervical diameters of 6–7 cm, it shifted to those
3. Expulsive effort

The expulsive forces at a certain time can be expressed as the expulsive activity, and the total amount of expulsive activity exerted in a certain period can be expressed as the expulsive effort. The values of expulsive effort were estimated by integration of the expulsive activity exerted during a certain period. The requirement of expulsive effort to dilate the cervical canal by one centimeter were 300–400 Hashimoto units ⋅ hours before cervical diameters of 6 cm, and 120–250 Hashimoto units ⋅ hours in the latter half of cervical dilatation. The expulsive effort per centimeter was smaller during the first stage of labor in multiparas than in primiparas, and the difference was remarkable in the latter half of cervical dilatation. At cervical diameters of 6 cm, in cases with the intact membranes, the values of expulsive effort per centimeter decreased suddenly from 280 to 130 Hashimoto

Table 2. Clinical characteristics of the three types of modes of changes in expulsive activities

<table>
<thead>
<tr>
<th>Type</th>
<th>I</th>
<th>II</th>
<th>III</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>9</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>Para</td>
<td>prim. &amp; mult.</td>
<td>prim. &amp; mult.</td>
<td>prim.</td>
</tr>
<tr>
<td>Bishop's pelvic score</td>
<td>10–12</td>
<td>3–11</td>
<td>4–8</td>
</tr>
<tr>
<td>Duration of first stage of labor (hrs.)</td>
<td>prim. 4–12</td>
<td>prim. 12–18</td>
<td>prim. 11–55</td>
</tr>
<tr>
<td>mult. 2–4</td>
<td>mult. 2–7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean duration of cervical dilatation</td>
<td>1.9</td>
<td>2.6</td>
<td>4.3</td>
</tr>
</tbody>
</table>

Note: (prim.: primiparae, mult.: multiparae)
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Fig. 8. Mean expulsive effort/cm of the three types in accordance with cervical dilatation

Fig. 9. Cumulative expulsive effort exerted from the initial diameter up to a cervical diameter of 10 cm (mean ± S.E.)

The cumulative expulsive effort from the initial diameter to the diameters of 10 cm showed a linear relation to the logarithm of the cervical diameter. And cumulative expulsive effort was smaller in multiparae than in primiparae always during labor (Fig. 9). The clinical meanings on the values of cumulative expulsive effort are shown in Table 3. In cases with small values, Bishop’s pelvic score was large and the first stage of labor was short. In cases with large values, however, the cervix was immature and the cervical canal was dilated slowly.

4. Efficiency index

The efficiency index expresses the ability of the expulsive effort to dilate the cervical canal. The equation to estimate the value of the efficiency index is as follows:

\[
\text{Efficiency index} = \frac{\log \text{final C.D.} - \log \text{initial C.D.}}{\Delta \text{expulsive effort}} \times 10^5
\]

(C.D.: cervical diameter in cm)

The average values of the efficiency index were 40–50 in the first half of cervical dilatation and decreased to 30–40 after cervical dia-

Table 3. Clinical characteristics of cumulative effort

<table>
<thead>
<tr>
<th>Cumulative expulsive effort (Hashimoto units•hours)</th>
<th>Mean</th>
<th>Less than mean − SD</th>
<th>More than mean + SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cervical diameter</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 cm–10 cm</td>
<td>1,700</td>
<td>500–700</td>
<td>2,500–3,000</td>
</tr>
<tr>
<td>5 cm–10 cm</td>
<td>1,300</td>
<td>330–600</td>
<td>2,300–2,700</td>
</tr>
<tr>
<td>Para</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>prim. &amp; mult.</td>
<td>10–12</td>
<td>2–7</td>
<td></td>
</tr>
<tr>
<td>Bishop’s pelvic score</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10–12</td>
<td>2–7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of first stage of labor (hrs.)</td>
<td>1.5–8</td>
<td>11–27</td>
<td></td>
</tr>
<tr>
<td>1.5–8</td>
<td>11–27</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Duration of cervical dilatation (hrs.)</td>
<td>1–2</td>
<td>2–5</td>
<td></td>
</tr>
<tr>
<td>5 cm–10 cm</td>
<td>2–5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(prim.: primiparae, mult.: multiparae)
meters of 7 cm. They were maintained at 50–60 during cervical dilatation in multiparae and dropped from 40–50 to 30 after cervical diameters of 7 cm in primiparae. After cervical diameters of 6 cm, they increased to 50–60 in cases with the intact membranes and decreased to 26 in cases with premature rupture of the membranes. The values of the efficiency index remained at average levels of 40–50 in type I, which decreased, however, in types II and III in conjunction with cervical dilatation after cervical diameters of 7 cm (Fig. 10).

5. Resistance index of the uterine cervix

The values of the resistance index of the uterine cervix indicate the rigidity of the cervix against dilatation of the cervical canal. This values are proportional to the sum of the expulsive effort exerted on the circumference of the cervical canal during the period which is required to dilate the cervical diameter by one centimeter. The value of the resistance index was calculated by the following equation.

\[
\text{Resistance index} = \frac{\Delta \text{expulsive effort}}{\text{final C.D.} - \text{initial C.D.}} \times \frac{\text{initial C.D.} + \text{final C.D.}}{2} \times \frac{1}{100}
\]

(C.D.: cervical diameter in cm)

The average values of the resistance index were in the range between 10 and 20, and showed no differences between primiparae and multiparae before cervical diameters of 6 cm, but after cervical diameters of 7 cm, they increased to 24 in primiparae and decreased to 10–12 in multiparae. The values of resistance index were always small in type I. In types II and III, however, they were large before cervical diameters of 6 cm. But after cervical diameters of 7 cm, in type II the values decreased to almost the values of type I, and in type III they increased remarkably (Fig. 11). From these findings, it may be indicated that in cases of type III the cervix is rigid and the duration of cervical dilatation is long. These values in cases with the intact membranes were little variations in the range of 10–15 in accordance with cervical dilatation, but in cases with premature rupture of the membranes they increased markedly to 16–24 after cervical diameters of 5 cm.

Discussion

The pressure between the fetus and birth canal (PFB) mentioned above is the strongest pressure in the contact area between the descending part of the fetus and the birth canal (lower uterine segment, cervix or vaginal wall). This is considered to be synonymous with the pressure between the fetal head and uterine wall (1959) and head-to-cervix pressure (1961) according to Lindgren or pressure between the fetal head and birth canal according to Schwarz et al. (1969).

The levels of PFB were found to be 2.2–2.3 times higher than those of amniotic pressure. Lindgren reported much higher values of 3–4 times than those of our findings. The reason
why this discrepancy was seen, would be the different nature of pressure sensors. His sensors were large (1.8 cm in diameter), thicker (6.6 mm thick) and fixed on more rigid metal plate than those of ours.

Although the continuous recording of accurate PFB has not been always easy and the expulsive activity may be hard to use for clinical monitoring of expulsive forces, the expulsive activity is found to be a useful indicator which can express expulsive forces, and it is proportional to uterine activity and expresses quantitatively the pressure activity exerted directly on the cervical canal.

The three types of expulsive activities, classified in accordance with the biodynamic characteristics of cervical dilatation, had different clinical courses during labor which would be caused by the form and softness of cervix and the descent of the fetus.

Alvarez et al. investigated cervical dilatation under the expression of ‘uterine work’ which was the sum of the intensities of amniotic pressure in a certain period. But “expulsive effort” mentioned here, is used in consideration of expulsive activity and its duration. Therefore, the word “expulsive effort” should indicate more accurately the mode of total expulsive work of labor than “uterine work”.

In the cases with premature rupture of the membranes, the expulsive effort/cm continued at large values of a mean of 250 Hashimoto units•hours/cm even after cervical diameters of 6 cm, the efficiency index decreased from a mean of 50 to 26 after cervical diameters of 5 cm and the resistance index increased from an average of 12-16 to 24 after cervical diameters of 5 cm. These findings coincided with the remarkable increases in intensity and expulsive activity after rupture of the membranes. The strong pressure, found after this point, exerted by the descending part of the fetus on the inner wall of the cervical canal during uterine contractions would be considered to accelerate the further cervical dilatation.

Summary

The pressure between the fetus and birth canal was recorded to estimate expulsive activity. New parameters such as expulsive effort, efficiency index and resistance index of uterine cervix were calculated and applied in an attempt to analyze the effect of expulsive forces on cervical dilatation.

This work was reported preliminarily at a symposium of the 30th Annual Scientific Meeting of the Japan Society of Obstetrics and Gynecology (Fukuoka, 1978) and at the 9th World Congress of the International Federation of Gynecology and Obstetrics (Tokyo, 1979). This investigation was supported with a Grant-in-Aid for Scientific Research from the Ministry of Education, Science and Culture.

References
9. Lindgren, L.: Biodynamics of the cervix during preg-
HISAKI, T. ET AL.  ACTA OBSTET GYNECOOL JPN Vol. 52, No. 11


(accepted: No. 4688, April 8, 1980)

概要 私達は37例の分娩時に、ストレンジージの小さなIE力トランスジューサを用いて胎児産道間圧を測定し、これから娩出力を知るexpulsive activityを求めた。Expulsive activityは子宮口開大にともなって增大し、初産婦の子宮口開大7cm以後ならびに破水後には著しく大きくなった。Expulsive activityが200橋本単位以下では子宮口開大度の如何にかかわらず、子宮口開大は進行せず、分娩は遅延した。胎児産道間圧は羊水圧と有意の相関があり、expulsive activityは羊水圧から求められるuterine activityと有意の相関が認められた。

子宮頸管の深さが異なる3部位で測定されたexpulsive activityの子宮口開大にともなう変動様式は3つに分けられた。子宮頸管の深い部位のexpulsive activityが子宮口開大の進行にともなって常に大きいものをI型とし、それが常に小さいものをII型とした。また、子宮口開大の前半ではI型の特徴をもつ、その後半ではII型の特徴をもつものをII型とした。このように生体力学的特徴から分けられたこれらの3型では、子宮頸管の形態的、物理的ならびに臨床的にそれぞれ異なる特徴を示した。

娩出力の子宮口開大作用を知るために、expulsive effort、効率指数および子宮頸管の抵抗指数などの新しいパラメーターを考案し、微弱陣痛、破水や子宮頸管の未熟性などが分娩時子宮口開大に及ぼす影響を臨床生理学的に解析した。