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Important role of oxytocin release during natural vaginal delivery for developing mother-infant bonding

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Abstract

At birth, a large amount of oxytocin (OT) is released into the systemic circulation in response to vaginal-cervical stimulation caused by the fetal body. Released OT induces uterine contractions during the labor, activating OT receptors on uterine smooth muscle cells. OT is also released within the brain and plays a pivotal role in initiating maternal behavior and mediating mother-infant bonding. However, there are serious concerns about the procedures of epidural anesthesia (EDA) and cesarean section (CS), in which hypothalamic OT release is impaired in the mothers. Early postpartum OT level decreased in EDA group, compared to non-EDA group. There was a negative correlation observed between OT levels and postpartum maternity blues in EDA group. Accumulated evidence suggests a long-term health risk of CS for the mothers as well as children. As OT dysregulation affects the brain development of the infant, CS is a risk factor for autism/ADHD in offspring compared with vaginal delivery (VD). Although synthetic OT infusion is frequently used in clinical settings for both inducing labor and augmenting labor progress, synthetic OT may downregulate OT receptors in the brain, which leads to impaired maternal behavior.

To develop better mother-infant bonding before, during and after the delivery, it is crucial to consider how to maintain high OT levels. By incorporating several approaches (social support, acupuncture, massage, music therapy, meditation, etc.), promoting a supportive and nurturing environment can further enhance OT release and facilitate bonding between mothers and their newborns.

Keywords: Acupuncture; Autism; Cesarean section; Depression; Epidural anesthesia; Maternal blue; Social support; Uterine contraction

1. Introduction

The mother-infant bonding is unique in its influence on the future of the offspring. In placental mammals, the helpless infant at birth is completely dependent on nutrition from the mother's milk and her body heat. This sustained closeness to the mother is a key for the infant's survival (1).

Oxytocin (OT), often called "love hormone" or "bonding hormone," plays a crucial role in fostering and maintaining the bond between a mother and her infant. Its importance in mother-infant bonding can be understood through several key functions, such as facilitating maternal behavior, strengthening emotional bonding and synchrony (2) (3).

OT is mainly produced in neurons at the paraventricular nucleus (PVN) and supraoptic nucleus (SON) of the hypothalamus. During pregnancy, OT expression is increased in the SON and PVN. Synthesized OT is secreted into the peripheral blood stream from the posterior pituitary (4) (5).

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During labor, the fetal body passing through the birth canal stimulates vaginal-cervical sensory neurons, which in turn simulates a large amount of hypothalamic OT release via the spinal cord (Fig.1). Plasma OT levels gradually increase during the first–forth stages of labor, with increasing size and frequency of OT pulses. Especially a large OT pulse occurs at the fourth stage (6).

Released OT into the systemic circulation induces uterine contractions during parturition by activating OT receptors on the uterine smooth muscle cells (6). OT is also released centrally during vaginal stimulation and parturition to act on OT receptors that are widely expressed throughout the central nervous system (CNS) (7).

The OT neuroendocrine system plays a key role in the initiation of maternal behavior after birth. Previous animal studies suggest an important role for OT in mediating mother-infant bonding. Maternal behavior is significantly impaired in post-partum rats following PVN lesions during pregnancy (8). When female rats receive OT antagonists immediately after parturition, maternal behaviour is significantly impaired (9). These suggest that centrally released OT is involved in post-partum maternal behavior.

The health-promoting effects of OT are mainly due to its anti-stress effects, anti-nociceptive effects and regulation of the autonomic nervous system. The anti-stress effects of OT are mediated via inhibition of corticotropin-releasing factor (CRF) through $GABA_A$ receptors (10). The anti-nociceptive effects of OT are mediated mainly by stimulation of opioid neurons. OT also regulates the autonomic nervous system via inhibition of catecholamine (CA) (1).

As OT plays an important role in the maternal care of offspring, the hypersecretion of OT during vaginal delivery (VD) is an essential factor to prepare for the onset of maternal behavior for newborn babies. VD stimulate the rapid and profound release of endogenous OT which helps in mother-infant bonding.

However, there are serious concerns about the procedures of epidural anesthesia (EDA) and cesarean section (CS), in which OT release is impaired in the mothers because of inactivation of vaginal-cervical sensory neurons. Less OT may interfere the development of maternal nature and mother-infant bonding. In this review article, the importance of natural VD is discussed from the viewpoint of physiological role of OT. It should be notified that every placental mammal has been utilizing the neuronal OT system to maintain and succeed the 'maternal love' for helpless newborn babies, since the dawn of our history.

While OT levels in infants before and after delivery were not well studied in humans, developmental changes in OT levels in the blood and pituitary were investigated in fetuses and infants of rats. Serum and pituitary OT levels increased gradually from day 21 pregnancy up to day 5 - 40 after birth (11). This suggests an important role of OT in infants as well to maintain infant-mother bonding.

2. Epidural anesthesia

As described above, OT release in response to vagino-cervical stimulation during parturition facilitates the mother-infant bonding after birth. Stimulation of the uterine afferent nerves excites the neuronal activity at the PVN, indicating that specific sensory afferents arrive at the PVN from the uterus. In addition, somatic afferents converge in this hypothalamic nucleus. Electrophysiological study showed that hypogastric and pelvic nerves are activated by a passage of the fetus down the birth canal (12). Stimulation of the uterine afferent nerves, the hypogastric and pelvic nerves, increases the activity of the OT neurons at the PVN (Fig. 1) (13).

It has been shown that the procedure of EDA during the labor impairs the sensitivity in response to vagino-cervical stimulation at parturition. In human studies, EDA during labor was associated with a fall in plasma OT. One hour later, OT levels decreased in EDA group, while they increased in control (non-EDA) group. There was no difference of the degree of cervix dilatation between the groups. Women with EDA had a longer labor compared with control women. EDA during labor may interfere with the release of plasma OT, which can be one of the mechanisms behind the prolonged labor (14).

Compared to non-EDA delivery, women who delivered by EDA had lower salivary OT levels and breast milk supply in early postpartum and at 1 month postpartum. Breast-feeding rates at 4 months postpartum was also reduced following EDA (15). It remains to be investigated whether low OT levels may affect maternal care.

In contrast, animal studies raise the possibility that EDA impairs maternal care. In sheep, several studies were carried out to investigate the effects of EDA performed either at the first signs of birth (early EDA), or little before expulsion (late EDA). When performed late, EDA altered maternal behavior only slightly when compared with controls. In contrast, severe deficits of maternal behavior were observed in the case of early EDA. Seven out of 8 primiparous mothers failed to show any interest in their newborn babies within 30 min of birth. Within the early group, effects of EDA were more marked in primiparous than in multiparous mothers.

Even in early EDA multiparous ewes that became maternal within 5 min after giving birth, a reduction in duration of licking of their newborns was noted, compared with the late EDA group. These same ewes established a normal, selective bond with their offspring within 2 hours after giving birth, as did the late EDA or control sheep. These results suggest the importance of genital stimulation for the rapid onset of maternal behavior in parturient sheep (16). OT concentrations in cerebrospinal fluid was significantly reduced in EDA-sheep, suggesting that central release of OT during parturition is disturbed by EDA. Thus, vagino-cervical stimulation caused by the fetus activates OT system, which induces the onset of maternal behavior in sheep.

Decreased postpartum OT levels following EDA may cause mental disorders of mothers. Early postpartum OT level decreased in EDA group, compared to non-EDA group. There was a negative correlation observed between OT levels and postpartum maternity blues in EDA group (17). Healthcare providers such as doctors, nurses, midwives, etc. should pay attention to EDA-received women who may need specific supportive care to prevent mental disorders.

Although not well established, recent studies raised the possibility that EDA may cause autism of infants due to low OT levels of mothers. Negative experiences in early life can lead to abnormal development of attachment systems, such as autism. Child abuse or neglect during childhood is associated with severe, detrimental long-term effects on the child's cognitive, socio-emotional and behavioral development (2) (3).

OT deficiency may be one of the causes of autism in children. Children with autism showed significant lower plasma OT levels than that of controls. The association of OT levels and social skills in autism children indicates the disturbances in OT system. (18).

In 2020, the association between EDA and the risk of autism in offspring was reported. Autism was diagnosed in 2039 children (1.9%) in the EDA group and 485 children (1.3%) in the non-EDA group. Within the EDA group, the risk of autism was significantly increased depending on the duration of EDA (less than 4 hours, between 4-8 hours, and more than 8 hours) (19). Recently, Qiu et al. (2023) examined the association of EDA and OT exposure with autism obtained from over 205,994 singleton vaginal births from 2008 to 2017. The children were followed until the end of 2021. In this study, 153,880 children (74.7%) were exposed to EDA and 117,808 children (57.2%) were exposed OT infusion. They found that during follow-up, 5,146 children (2.5%) were diagnosed with autism. OT exposure was higher in EDA-exposed children than in EDA-unexposed children (67.7% versus 26.1%), suggesting that EDA-exposure may have a risk of autism. The risk is further increased if synthetic OT was administered during labor (20). However, it remains unknown whether OT infusion may affect mother-infant bonding in EDA exposed mothers. Further studies are needed to clarify whether low levels of maternal OT levels after EDA may reduce OT levels of infants.

Due to the lack of normal sensory input from the genitalia induced by the fetal body, low levels of endogenously released OT are observed following EDA at parturition, which may disrupt maternal behavior (Fig.2). Therefore, natural OT release is preferable for the development of maternal behavior and mother-infant bonding.

3. Cesarean Section (CS)

The age when women began to option for elective CS on request was a turning point in the history of delivery. CS rates worldwide are increasing nowadays. Historically, CS was primarily performed for medical reasons, such as fetal distress or maternal health concerns. However, with advancements in medical technology and changing attitudes towards childbirth, some women began to request CS for reasons other than medical necessity. Today, in many countries, women are likely to select CS on request, which may cause a reduction of endogenous maternal OT release (Fig. 2). Labor care guide of World Health Organization (WHO) aims to improve the quality of care for women during labor (21).

Understanding the impact of reduced OT release, particularly in women who undergo CS, on mother-infant interaction and breastfeeding is crucial (1). Plasma OT levels and breast-feeding were evaluated between the women with emergency CS and those with normal VD on day 2 postpartum. VD mothers had significantly more OT levels than CS mothers. OT levels and the duration of the exclusive breast-feeding period were highly correlated in VD group on day 2. Thus, development of an early secretion of OT pattern is important for breast-feeding (22).

Accumulated evidence suggests a long-term health risk of CS for the mothers as well as children. Matsumura et al. (2023) examined the relationship between CS and parenting stress. They showed significant increase in parenting stress scores for the CS group from as early as 1.5 years of age. This increase was primarily due to an increase in difficult child factor score, such as stress from the child's temperament or behavior and not in the score for factors related to parenting distress. The parenting stress is increased when a child has an autism spectrum disorder, allergy, or physical disease (23).

CS-delivered children are known to exhibit an excessive stress response to acute psychological stressors even in adulthood. It has been suggested that passage through the birth canal is critical in the development of the core stress system. As CS bypasses this system, CS delivered infants may receive a negative influence on strong stress experiences. It has also been reported that CS-delivered children have low diversity of gut microbiota, and such low diversity is related to psychiatric disorders (23).

It seems that CS causes higher parenting stress, may be due to difficult child factors. It is highlighted the importance of paying particular attention to the mental health of both mother and child in case of CS. Others also demonstrated the association between CS delivery and autism. As mentioned above, children with autism have significantly lower plasma levels of OT. During normal birth, OT is secreted, reaching a peak in the first hour after birth. However, this peak is absent when delivery occurs via CS (24). A recent study suggests an adverse effects of CS on newborn babies as well. Offspring born via CS had a higher incidence of attention deficit hyperactivity disorder (ADHD). In the meta-analysis, CS was a risk factor for autism/ADHD in offspring compared with VD (25).

Delivery by CS now makes up 32% of all births in US. Meta-analyses have estimated that delivery by CS is associated with more than 50% increased risk for childhood obesity by 5 years old. This association is independent of maternal obesity, breastfeeding, and heritable factors.

Animal studies showed that prairie vole delivered by CS had consistently greater bodyweights than those born by VD, despite having lower food consumption and greater locomotive activity. CS delivery vole showed less OT expression within the hypothalamus (26). OT has been shown to cause weight loss by reducing food intake and increasing energy expenditure in vole (27). These indicate that reduced OT system after CS delivery may increase offspring body weight.

CS delivery induces autism-like behaviors in offspring mice, while these changes were improved by OT treatment to their mothers. In contrast, treatment with OT receptor antagonists before natural delivery induces autism-like behaviors. These strongly suggest that insufficient OT release of mothers during delivery is a trigger for autism (28).

Shojaei et al (2021). evaluated the effect of walking during late pregnancy on the outcomes of delivery. The intervention group performed walking (4 times per week, each time for 40 min) from the 34th week of pregnancy until the time of delivery. The control group just received the routine prenatal care. Walking significantly increased the number of natural VD, while it decreased CS delivery cases without any adverse effect on the newborn's Apgar score (29).

Evidence-based strategies should be utilized to improve outcomes and decrease the risk of CS delivery. Recommendations should be shared across team members, to create a model promoting a safe patient care (30).

4. Synthetic OT exposure

Previous studies suggest that labor may be associated with long-term, behavioral and physiological adaptations in the mother and infant, involving epigenetic modulation of OT release and OT receptors. In the peripartum period there are marked increases of OT in the peripheral and central (PVN and SON). During parturition, OT receptors are highly upregulated within numerous brain regions, including bed nucleus stria terminalis (BNST), medial preoptic area (mPOA), medial amygdala (MeA), nucleus accumbens (NAcc), etc. These OT receptors respond to endogenously released OT to mediate the onset of maternal behavior (31). It is reasonable to consider, but have not yet proven, that exogenously applied synthetic OT may downregulate OT receptors in the brain, which leads to impaired maternal behavior.

Synthetic OT infusion is the current first-line agent to induce and augment labor. Administered OT acts on receptors located on the membrane of the smooth muscle cells of the myometrium. During the stages of labor, its binding causes uterine myofibers to contract.

It is generally thought that continuous infusion of OT for labor induction in nulliparous patients is superior to intermittent OT infusion, because it shortens delivery time, decreases chorioamnionitis rate, and improves maternal satisfaction, without any adverse effects on mothers and babies (32).

On the other hands, continuous OT exposure to augment uterus contractions may cause OT receptor desensitization of the uterine muscle cells and further reduce the uterine response to OT, resulting in an increased risk of uterine atony. Myometrial contractility significantly increased during subsequent short intermittent OT exposure, compared to continuous exposure. Brief intermittent OT stimulations resulted in improved contractile force than continuous exposure. This suggests the OT receptor desensitization is attenuated by intermittent exposure (33).

OT is administered according to different dose regimens at increasing rates from 1 - 3 mU/min to a maximal rate of 36 mU/min for 15 - 40 min intervals. The total amount of OT given during labor can be 5 -10 U. High-dose infusions of OT may shorten the duration of labor by up to 2 hours, compared with no OT infusion.

When OT is administered, the plasma concentration of OT increases in a dose-dependent manner. Plasma OT levels are increased by 2-3 folds above basal at infusion rate of 20 - 30 mU/min (3).

It is reported that the risk of postpartum hemorrhage is increased in women receiving high amounts (more than 4,370 mU) of OT infusion during labor. Because women's birth experience has a major impact on their future mental health, the dose of OT infusion should be carefully assessed (34). OT should be administered with caution because high plasma levels of OT may induce uterine overstimulation, which has a potential negative consequence for the fetus and the mother.

Maternal circulating OT levels extremely increases in response to infusions of synthetic OT. It is generally thought that OT administered at recommended dose levels does not cross the placenta or maternal blood brain barrier (BBB) (6). In contrast, Carter mentioned that OT would pass through the placenta and the BBB, which may cause negative effects on the fetus and the maternal brain (35). If higher amounts of OT are given, OT may pass the placenta and maternal BBB (3), which may downregulate OT receptors in the brain of infants and mothers leading to impaired mother-infant bonding.

Although OT infusion itself may not cause any mental disorders in children (20) (36), the relationship between OT exposure and the risk of autism of infants are unknown. Since OT administration is widely used in the obstetric ward, these potentially deleterious effects are concerned.

Some studies have indicated the increased risk and autism among children prenatally exposed to OT. OT was used in 31% and 46% of the included deliveries in Denmark and Finland, respectively. In crude analyses, prenatal OT was associated with an approximately 20% increased risk of ADHD and autism, but there no significant association observed between synthetic OT use and ADHD or autism (37). Guastella et al. (2018) proposed that exogenous administration of OT has no clinically significant negative impact on the long-term mental health of children (38).

It remains unclear whether the synthetic OT causes autism by desensitization of OT receptors in the fetal brain. The permeability of the BBB in the fetus to OT is discussed and concluded that routine doses of synthetic OT (6 mU/min) are not a significant cause of autism attributable to OT receptor desensitization (39). Further studies are needed whether higher doses of OT may cause OT receptor desensitization of the fetus brain.

Zhou et al. studied the potential effects of synthetic OT infusion on neonatal neurobehavioral development. Infants' activities (such as eating hands, moving body, occurrence time of raising head or turning head, locating areola and licking nipples) were significantly reduced after OT infusion. The intrapartum administration of synthetic OT was associated with the expression of neonatal instinctive breastfeeding. With increases in OT dose, the effect of breast-seeking activity and breast attachment was more significant, and the association of synthetic OT on sucking and breastfeeding was dose-dependent within 3 days after birth (40).

The research regarding reincarnation has collected more than 2,000 cases of children claiming to have past-life memories [56]. Carman has interviewed waking adults and children who report pre-birth experiences and fully remember their pre-birth existence. Pre-birth experiences suggest that we come from the same place to which we return. People with pre-birth memories remember existing in a luminous world before birth and recall how we travelled to our mother's womb [57].

If this is the case, it is conceivable that every infa has a soul and will, even though they remain in their mother's womb. It should be noted that if the uterine contractions are weak, they may think that we are not ready to come out and they would resist being forced by the synthetic OT exposure. Although this idea has not yet been scientifically proven, there would be other options available before starting OT infusion, such as somatosensory stimulation (nipple massage and acupuncture, etc.) to promote endogenous maternal OT release. Birth is the collaborative program of nature, carried out by both mother and child. It is a reminder that while medical interventions can be necessary and beneficial, respecting the body's natural processes is equally crucial.

5. How to maintain high OT levels for developing better mother-infant bonding before, during and after the delivery?

OT is deeply involved in social bonding, trust, and maternal behavior. Its release during VD helps facilitate the bond between mother and baby. This hormone not only stimulates uterine contractions during labor but also plays a crucial role in promoting nurturing behaviors in mothers towards their infants after birth.

As mentioned earlier, maternal OT levels are reduced following CS and EDA delivery, which might interfere mother-infant bonding. There are several strategies to compensate OT insufficiency observed in mothers exposed to CS and EDA.

5.1. Mental support

OT has been extensively studied regarding to its effects on trust and prosocial behavior. OT has unique effects of decreasing background anxiety without affecting learning and memory of a specific traumatic event. Increased OT expression during traumatic events prevent the formation of aversive memories (41).

Social support, in the form of companionship from partners, family members, or friends, can provide emotional reassurance and comfort, which in turn can promote OT release. Psychology tells us that social support is an important factor for mothers during labor and delivery. The presence of a supportive person during labor can shorten the duration and decrease the rate of CS delivery. Mothers participating in midwife-led continuity models of care during pregnancy were more likely to have a spontaneous VD and less likely to have regional analgesia, instrumental VD, preterm birth, and fetal loss. Social support may act via modulation of OT release during labor and delivery (3). Every family around the mother should recognize that their intense empathy and mental support for the mother stimulates her endogenous OT release.

It has been shown that affiliative behaviors may upregulate hypothalamic OT expression, which in turn attenuates stress responses (42). A positive social interaction is bidirectional, giving and receiving empathy. Affiliative behavior toward others reduces stress responses via up-regulating hypothalamic OT expression (42). Thus, giving affection and empathy to others is a key in upregulating hypothalamic OT expression. Every mother can recognize that her intense passion and love to her infants stimulates her own OT release, which promotes her wellbeing (43). Upregulated OT expression would help to maintain mental and physical health both of mother and infant.

5.2. Somatosensory stimulation

At the beginning of Covid-19 pandemic, CS, immediate separation of mother-infant dyads, avoid skin-to-skin contact/breast-feeding were routinely performed to reduce vertical and horizontal transmission risk (44).

In contrast, immediate skin-to-skin contact, and early breast-feeding are recommended for the wellbeing of the neonate. One group (Group 1) was provided immediate skin-to-skin contact and breast-feeding in the operating room during CS delivery. Another group (Group 2) breast-fed their babies 1 h after the CS delivery. OT levels and oxidative stress were evaluated between two groups. Oxidative stress levels were lower in Group 1 than Group 2. There were negative correlations observed between OT levels and post-operative oxidative stress. Thus, immediate skin-to-skin contact and breast-feeding during CS reduce maternal oxidative stress via upregulated OT system (45).

OT released by immediate skin-to-skin contact and breast-feeding during CS acts as anti-stress effects. Anti-stress effects of OT are mediated by its inhibitory effect on CRF expression (46). The inhibitory effect of OT on CRF expression is not a direct effect on CRF neurons. GABAergic neurons are in the immediate surroundings of the PVN (peri-PVN). These neurons of peri-PVN inhibit CRF synthesis via $GABA_A$ receptors (10).

Postpartum depression is observed in 10 - 22% of women after birth, which affects their health and the health of their newborn babies. Kangaroo care has many health benefits for both of mothers and her newborn babies. Kangaroo care is useful to decrease the risk of postpartum depression. Skin-to-skin contact during kangaroo care is known to trigger the release of OT, which may minimize the risk of depressive symptoms as well as decrease maternal stress (47).

In 1993, Uvnas-Moberg showed that various types of somatosensory stimulation (touch, massage, acupuncture, thermal stimulation, and vibration) can increase OT levels in plasma and cerebrospinal fluid in anesthetized rats (48). Pleasant touch is recognized to increase OT release (41). These raise the possibility that manual therapies such as touch, massage and acupuncture may act on OT neurons at the hypothalamus. Acupuncture increases the number of OT-immunopositive cells at the PVN in rats (49).

Thus, acupuncture and massage are candidates to stimulate endogenous OT, which may act not only peripherally to stimulate uterine contraction, but also centrally to promote maternal nature. Recent review article demonstrated that acupuncture is effective for the patients with depression (50). Therefore, acupuncture is also applicable for treating maternity blue.

5.3. Music therapy

Music has been found to have a positive impact on OT release, particularly music with slow tempos and soothing melodies. Recent study showed that listening to the music of Mozart CD increases salivary OT secretion (51), indicating a potential use of music therapy to upregulate OT system of mothers, which may lead to develop maternal nature.

5.4. Meditation

Mindfulness meditation is known to improve the remission and reduction of depression during pregnancy and may be useful for the clinical treatment of pregnancy depression (52). Kindness-based meditation enhances prosocial emotions, social cognitive skills, and well-being (53). Others showed that salivary OT secretion is significantly increased by the meditation, which uniquely motivates the feeling of altruism and appreciation (43).

Sophrology Is a combination of Western relaxation and Eastern yoga and meditation. The study was performed to evaluate whether prenatal sophrologic preparation may decrease maternal stress during labor. The number of women requiring OT infusion tended to be lower in the group undergoing sophrologic preparation (58.0%), compared to control (72.5%, $P = 0.07$) (54), raising the possibility that endogenous OT release is stimulated by sophrology. Further studies are needed to clarify the beneficial effects of prenatal relaxation/meditation procedure to decrease adverse maternal events. Once maternal OT release is confirmed by any type of meditation, this would be a good candidate to treat maternal distress before, during and after delivery.

5.5. Orgasmic Birth (Joy of Birth)

More than 4 million babies are born in the US every year. Many women experience childbirth as a routine or painful event. Most women trust that all the techniques and procedures offered are safe and accept EDA for pain relief. However, the procedure has many negative short- and/or long-term effects on mothers and babies that should be considered and questioned, as mentioned earlier.

As an experienced doula, Mrs. Pascali-Bonaro showed that childbirth is a natural process to be enjoyed and cherished, in her acclaimed film 'Orgasmic Birth' (https://www.orgasmicbirth.com). Based on this successful documentary, Davis and Pascali-Bonaro offered an enlightening program to help women achieve the most empowering and satisfying birth experience possible (55).

With nearly a third of American women having a surgical birth, Davis and Pascali-Bonaro raised serious concerns about the risks that overuse of CS poses to mothers and babies. ‘Orgasmic Birth’ offers a provocative perspective, challenging cultural narratives surrounding childbirth. It suggests that birth can be not just a physical process but also a deeply emotional and spiritual experience, defying conventional perceptions of pain and fear. By highlighting the potential for ecstatic moments during childbirth, it invites viewers to reconsider their assumptions and approach birth with a more holistic perspective (55).

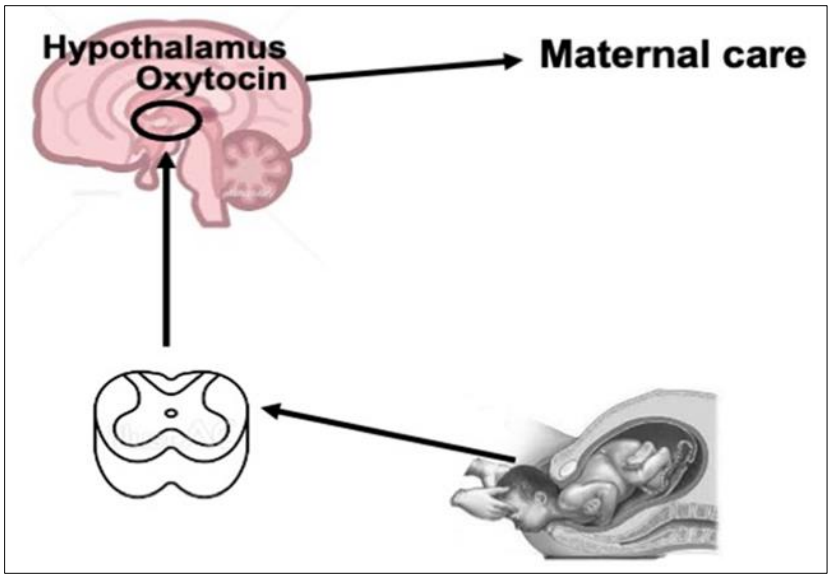

Figure 1 At birth, the fetal body activates vaginal-cervical sensory neurons, which in turn simulates a large amount of hypothalamic oxytocin (OT) release via the spinal cord. OT neuroendocrine system in the brain plays a key role in the initiation of maternal behavior after birth

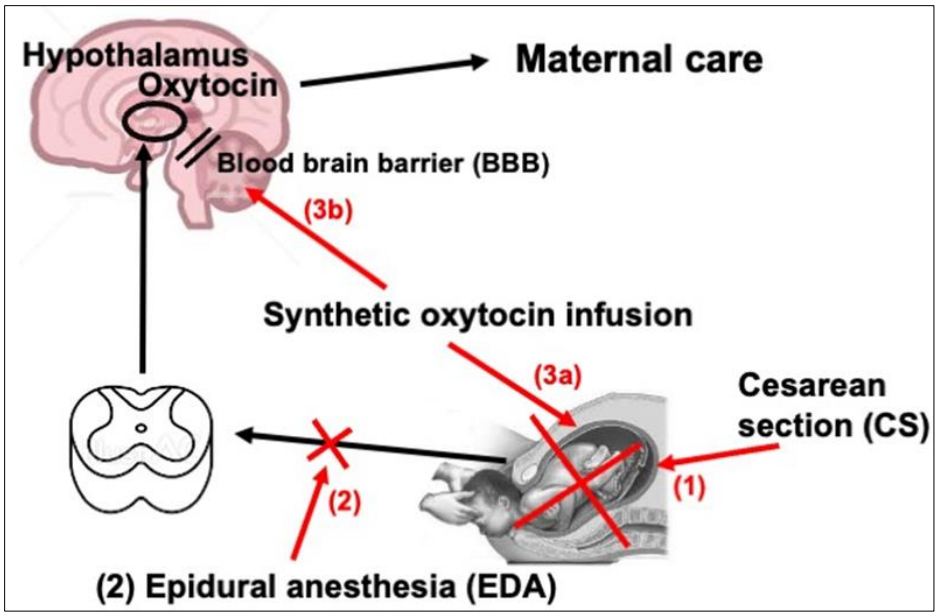

Figure 2 Maternal OT release from the hypothalamus is significantly reduced following CS (1) and EDA (2), which may interfere to develop maternal care. OT infusion may affect maternal OT system (3b) and infant body (3a)

Abbreviation

- Attention deficit hyperactivity disorder (ADHD)
- Blood brain barrier (BBB)
- Cesarean section (CS)
- Epidural anesthesia (EDA)
- Oxytocin (OT)
- Vaginal delivery (VD)

6. Conclusion

OT has multiple important effects during labor, and several OT-linked mechanisms cooperate to promote the birth of the neonate. OT released within the brain influences maternal physiology and behavior during labor. Previous studies suggest an important role for OT in mediating mother-infant bonding. At birth, the fetal body stimulates vaginal-cervical sensory neurons, which in turn simulates a large amount of hypothalamic OT release via the spinal cord. OT neuroendocrine system in the brain plays a key role in the initiation of maternal behavior after birth. There are serious concerns about the procedures of epidural anesthesia (EDA) and cesarean section (CS), in which OT release is impaired in the mothers. Less OT may interfere the development of mother-infant bonding.

Decreased postpartum OT levels following EDA may cause mental disorders. There was a negative correlation observed between OT levels and postpartum maternity blues in EDA group. The associations of OT levels and social skills in children with autism indicate disturbances at various levels of OT system. There is a long-term health risk of CS for the mothers as well as children. CS causes higher parenting stress, may be due to difficult child factors. OT dysregulation may affect the brain development of the infant. CS is a risk factor for autism/ADHD in offspring compared with VD. Evidence-based strategies should be utilized to improve outcomes and decrease the risk of complications and delivery following CS. Synthetic OT is the current domestic first-line agent to induce and augment labor. During parturition, OT acting via the OT receptors is particularly important for the onset of maternal behavior. Exogenous infusion of synthetic OT may downregulate OT receptors in the brain, which leads to impaired mother-infant bonding.

Maintaining high OT levels throughout the perinatal period can have significant benefits for mother-infant bonding and overall well-being. Social support, acupuncture, massage, music, and meditation have all been explored as potential ways to stimulate maternal OT release.

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