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The Influence of Positioning on Spontaneous Movements of Preterm Infants

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Abstract. [Purpose] In this study, we quantitatively evaluated how the positioning program influenced the movement patterns of preterm infants in the neonatal intensive care unit (NICU). [Subjects and Methods] Spontaneous movements of 12 low-risk preterm infants were video-recorded at 38 or 39 postmenstrual weeks of age (PMA). Six of them (positioning group) received a positioning program from birth to 35–36 weeks of PMA while the other 6 (non-positioning group) did not. We attached reflective markers on the infant's wrists and ankles in the supine position and filmed them from above. By using a two-dimensional image analysis system, we digitized the wrist and ankle trajectories and analyzed the data by calculating several statistics. [Results] Infants in the positioning group brought their hands to the midline or crossed their hands over the midline and showed more variation in velocity of movements than those in the non-positioning group. We also noticed that infants in the positioning group exhibited and maintained a movement pattern similar to that of full-term infants at 1 month after the positioning program was terminated. [Conclusions] These results suggest that appropriate positioning of preterm infants facilitates flexion posture and movement patterns toward the centre of the body similar to foetuses in the uterus.
Key words: Positioning, Preterm Infants, Spontaneous movements

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INTRODUCTION

Preterm newborn infants in the neonatal intensive care unit (NICU) characteristically assume a hypotonic extension posture. It is difficult for them to assume a flexion posture that is normally seen in full-term infants because of their low postural tone, the influence of gravity, and the lack of flexor tonus[1,2)]. They are exposed to gravity before their bodies can deal with it and are forced to live and cope in an environment different from the protected environment in the uterus. They do not exhibit adequate flexor tone, which is normally exhibited by full-term infants, and even when they reach their full-term, they often show extended posture[3,4)]. Full-term infants experience non-nutritive sucking as they are tucked in the flexion posture in the uterus. In this position their hands are brought toward the mouth, and thus, they are introduced to the basic feeding activity. They can maintain the flexion posture and often bring their hands toward the midline, look at their hands, and reach forward. In contrast, preterm infants tend to demonstrate hypotonic extension postures and find it difficult to bring their hands to the midline. They cannot adequately control the movements which enable them to sustain the symmetrical pattern of total flexion and move out smoothly from the flexion

Fig. 1. Positioning in the NICU.
Wrapping the infants firmly in the flexion posture with the mat provides them with stability in the prone position. Surrounding and enclosing the infants like a nest with the mat provides them with an opportunity to bring their shoulders forward, bring their fingers to their mouths, and suck on their fingers in the flexed position in supine and side-lying. Putting a towel in front of the infant helps him to keep his arms forward in side-lying.

posture; this is because of their immature central nervous system and lack of proximal stability[5–7] . As compensation, they attempt to gain postural stability by fixing against a firm surface, usually the mattress on the bed in the NICU, and easily develop excessive extension postures, i.e. the so-called W-position of the arms and frog-leg posture[8,9]. These characteristic postures can influence their motor development in the future[10–12]. In addition to these problems in structural and movement patterns, there are many studies that report preterm infants also have problems in looking at their hands, realizing their body image, developing cognition and sociality, and interacting with their environment[13–20]. To support these preterm infants, a positioning program has been introduced to the NICU[21].

The purpose of this study was to assess how the positioning program influenced the infant movement patterns by quantifying the spontaneous movements of preterm infants in the NICU. Observing their movement patterns, we especially focused on the following issues and quantified them because they clearly exhibited differences between the positioning group and the non-positioning group. (1) Do both of an infant's hands approach each other during spontaneous movements? (2) How often do infants bring their hands to the midline and cross their hands at the midline? (3) The velocity of the movements in the positioning group appeared to us to be more varied than that of the non-positioning group: ergo, is there really a difference in the velocity of spontaneous movements of the lower extremities between the positioning group and the non-positioning group?

In this study, we used the positioning mat developed at Nagano Prefectural Children's Hospital for preterm newborn infants. This is a convenient positioning tool which is used to wrap or enclose infants to maintain the upper and lower extremities in a flexion posture similar to that within the uterus. This mat is made of cloth with a precut quilted surface and attached velcro; therefore, it can easily be formed and shaped as required. We used the mat for each infant in the prone and supine positions as well as the side-lying position, depending on their condition. Wrapping the infants firmly in the flexion posture with the mat provides them with stability, and surrounding and enclosing the infants like a nest with the mat provides them with an opportunity to bring their shoulders forward, bring their fingers to their mouths, and suck on their fingers in the flexed position. Figure 1 shows examples of the positioning in the NICU.

SUBJECTS AND METHODS

Subjects

Twelve preterm infants were included in this study. Six of them formed the positioning group. They were low-risk preterm infants born at 25–32 weeks PMA with birth weights of 811–1,562 g in the NICU at the Nagano Prefectural Children's Hospital, Japan. Another 6 infants formed the non-positioning group. They were low-risk infants born at 26–33 weeks PMA with birth weights of 925–2,364 g. They were in the NICU at the Fukui

Medical University Hospital, Japan. We used the following selection criteria: birth weight $>25^{th}$ and $<90^{th}$ centile, uneventful pregnancy and delivery, an Apgar score of >7 at 5 min, and the absence of obvious neurological abnormalities, severe sepsis, chromosomal defects, or metabolic disorders. The infants in the positioning group received the positioning program depending on their condition, from birth until 35–36 weeks PMA. The infants in the non-positioning group did not receive any specific positioning program. This study was approved by the ethical committee of both hospitals. All parents provided their informed consent.

Methods

The spontaneous movements of the participants were videotaped when each infant was 38–39 weeks PMA. We attached reflective markers to the infants' wrists and ankles in the supine position and filmed them from above when they were awake and moving good-humoredly (state 4 described by Prechtl [22]). We filmed the infants for 5–10 minutes, paying constant attention to the change in the infant's state. We selected 2 min and 40 s during the time of continuous movement and digitized the wrist and ankle trajectories at every 1/30 s using a 2-dimentional image analysis system (Frame-DIAS; DKH, Japan). This system requires only one video camera and can be easily set up in the limited space of a NICU. We note that a 3-dimensional image analysis system which requires several video cameras was not available for our experiments. The original data are Cartesian coordinates measured as pixels on the video image. The y coordinate spans from the lower extremity to the head of the infant, and the x axis spans from the right to the left side of the infant's body. We normalized the data by dividing all the figures by each infant's crown-rump length (CRL) to eliminate differences in infants' sizes. CRL is the length between the head and bottom along an infant's body axis and is usually used as the measurement scale in ultrasonograms obtained during early gestation. We used this measure for correcting data because it is relatively easy to measure. Thus, the x axis and y axis show positions of extremities relative to the CRL. All calculations in this paper were performed with the statistical system R (http://www.r-project.org/).

RESULTS

The upper panels of Fig. 2 show typical examples of the trajectory of the extremities for each group. The positions of each extremity were recorded every 1/30 s, 4,600 times. They have been plotted as Cartesian coordinates and connected by line segments between the consecutive time intervals. In the case of the positioning group, the trajectories of the right and left hands sometimes crossed, and this phenomenon was also observed in the right and left legs as shown in the upper left panel of Fig. 2. On the other hand, in the non-positioning group, the trajectories of the right and left extremities did not meet as shown in the upper right panel of Fig. 2. In other words, the movements of the extremities tended to be concentrated at the centre in the positioning group, while in the non-positioning group, movement of the extremities tended to be around the periphery. We also plotted the values of the x coordinates of the limb movements on the vertical axis against the frame numbers as the horizontal axis (lower panels of Fig. 2). These figures clearly show that the right and left hands of the infants in the positioning group sometimes crossed each other; however, in the non-positioning group, the infant's right and left hands never crossed. To quantify this phenomenon we first calculated the difference between the right hand x value and left hand x value for each frame. As the left hand on account of its position usually has a larger x value than the right hand, this value is usually greater than 0. If this value is less than or equal to 0, the right and the left hands crossed or touched at around the centre of the body. We counted the number of instances this occurred and calculated it is a proportion of the number of whole sampling frames (4,600 frames). The results were 1.43, 0.83, 0.72, 0.65, 0, and 0% (mean=0.61%) in the positioning group and 0% for each subject in the non-positioning group. In other words, all infants in the non-positioning group never brought their hands together; however, the majority of infants in the positioning group brought their hands to the midline or cross their hands for a while during movements.

We investigated these movements of the hands from another viewpoint. We denote the left hand x value at frame t as $l(t)$ and the right hand x value at frame t as $r(t)$. We calculated the difference between them with the following formula $l(t)–r(t)$. Then we computed the mean values for each infant:

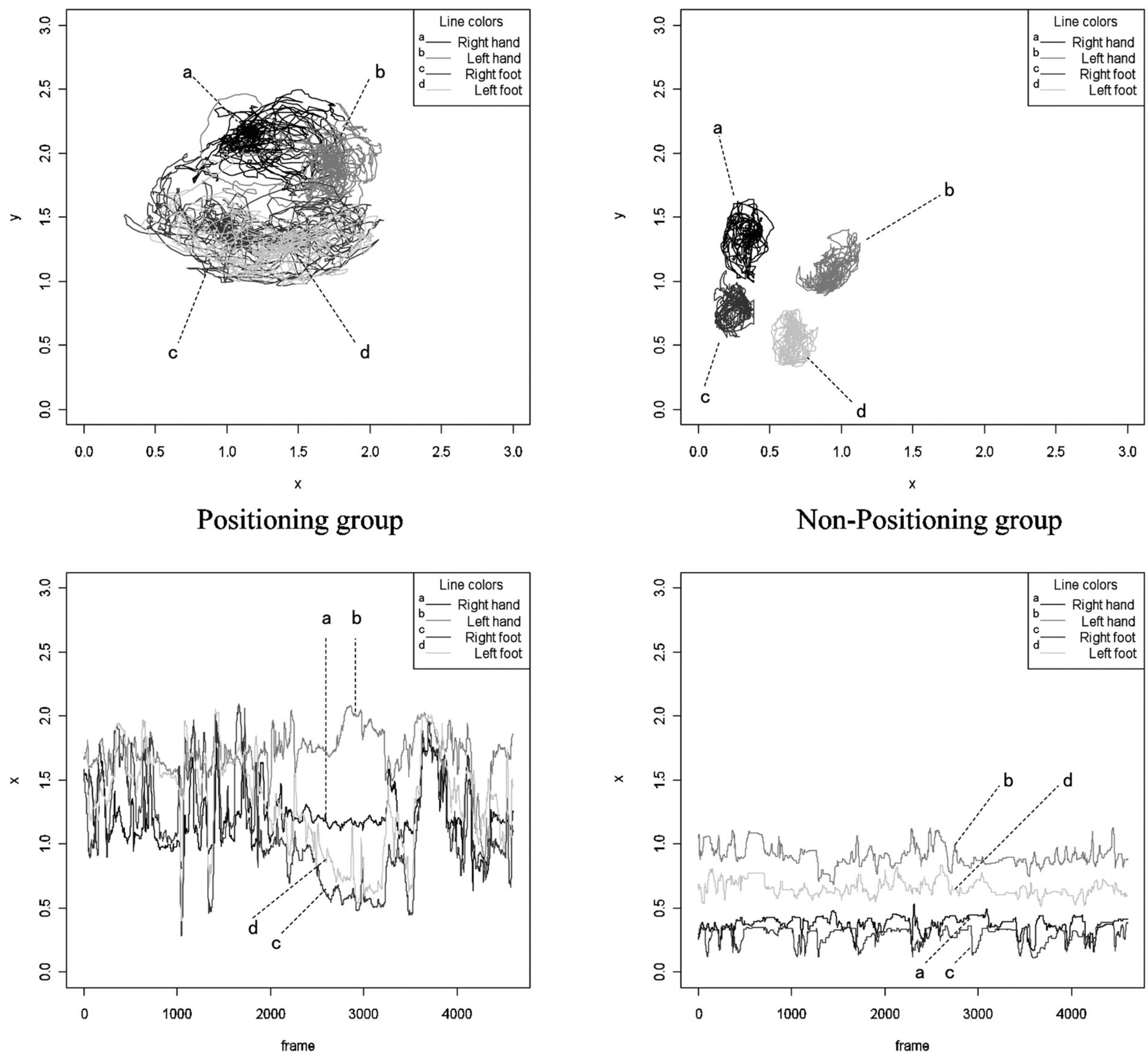
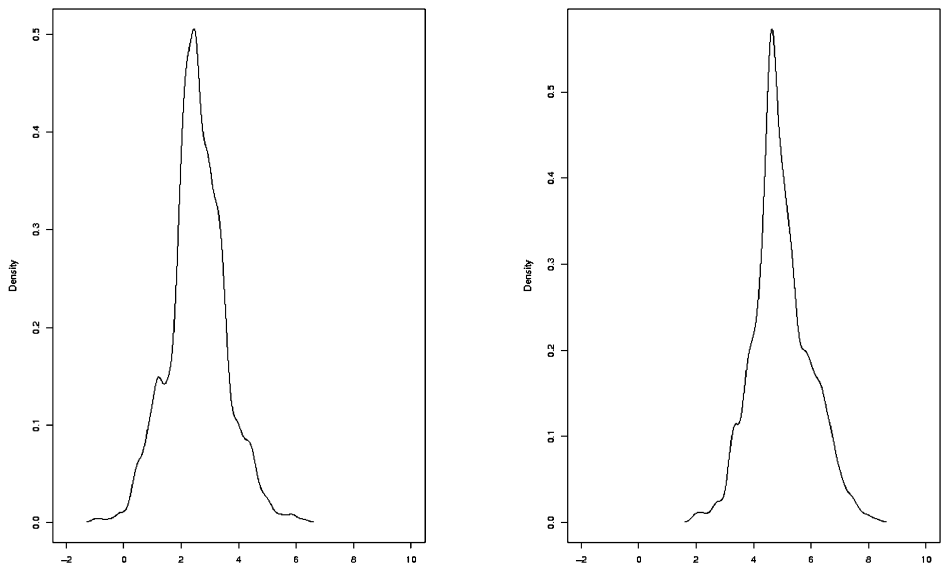


Fig. 2. Examples of trajectories and time series plots in x direction.
Each upper panel displays trajectories of the extremities of one infant from the positioning and the non-positioning groups. The movements of the extremities tended to be concentrated at the centre in the positioning group, while in the non-positioning group, movements of the extremities tended to be around the periphery. Lower panels display x values of the limb movements with frame (i.e., time). They also show clearly that both hands of the infants in the positioning group sometimes crossed each other; however, in the non-positioning group, the infant's hands never crossed.

they were 3.98, 3.75, 2.81, 2.56, 2.43, and 2.41 in the positioning group and 7.55, 4.96, 4.84, 4.41, 4.31, and 4.12 in the non-positioning group. To see the behavior of difference between both hands, we estimated their probability densities (using the kernel method available in the software, R). Figure 3 displays an example of the graph of the estimated density of the distance between both hands on the x-axis for each group. All the densities that were estimated in our research are unimodal, thus, the means express the proper "center" of the densities. It is clear that means of the positioning group are nearer to 0 than those of the non-positioning group. This indicates that the hands of the infants in the positioning group approached each other to a greater extent than those of the infants in the non-positioning group. This result was confirmed by the Wilcoxon rank sum test (p=0.022%). This p value



Positioning group (mean=2.56) Non-Positioning group (mean=4.96)

Fig. 3. Examples of estimated densities of differences between hands in the x direction. These examples illustrate that the distances between both hands on the x-axis are distributed unimodally. The mean of distances for infants in the positioning group, which shows the center of the distribution, is nearer to 0 than that for infants in the non-positioning group.

indicates that the means of the two groups are clearly different. When we observed the recorded video, we noticed that the velocity of the movements in the positioning group was more varied than that of the movements in the non-positioning group. To confirm this finding, we compared the velocities of the right foot y values of each infant. The movement of the lower extremities was appropriately measured in the y direction because these movements are simple and mainly occur along the y direction. As a measure of velocity, we used the differences between the consecutive y values and calculated the standard deviation of these values to indicate the variation in velocity. Figure 4 shows the time series and velocity plot of the right foot y values. The standard deviations in the positioning group were 0.0162, 0.0130, 0.0125, 0.006505, 0.00967, and 0.00973 and those in the non-positioning group were 0.00867, 0.00847, 0.00843, 0.00803, 0.00731, and 0.00495. We concluded that the variations in the velocity of the right foot were greater in the positioning group than in the non-positioning group (Wilcoxon rank sum test; $p = 4.1\%$).

DISCUSSION

This study demonstrated that the spontaneous movement patterns of preterm infants who received the positioning program in the NICU were different from the movement patterns of preterm infants who did not receive the positioning program. Infants in the positioning group brought both their hands to the midline or crossed their hands during movements even 1 month after the positioning program was terminated. On the other hand, infants in the non-positioning group exhibited the typical flattened postures of preterm infants, and they did not bring their hands to the midline or cross them. Furthermore, when the movement velocities of the infants' legs were analysed, the variation in the movement velocities of the infants in the positioning group was higher than that in the movement velocities of the infants in the non-positioning group.

The environment in the NICU influences the neurological development of infants just like the intrauterine environment affects foetuses. Positioning is one of the techniques used to make the environment of the NICU similar to that of uterus. The positioning technique for preterm

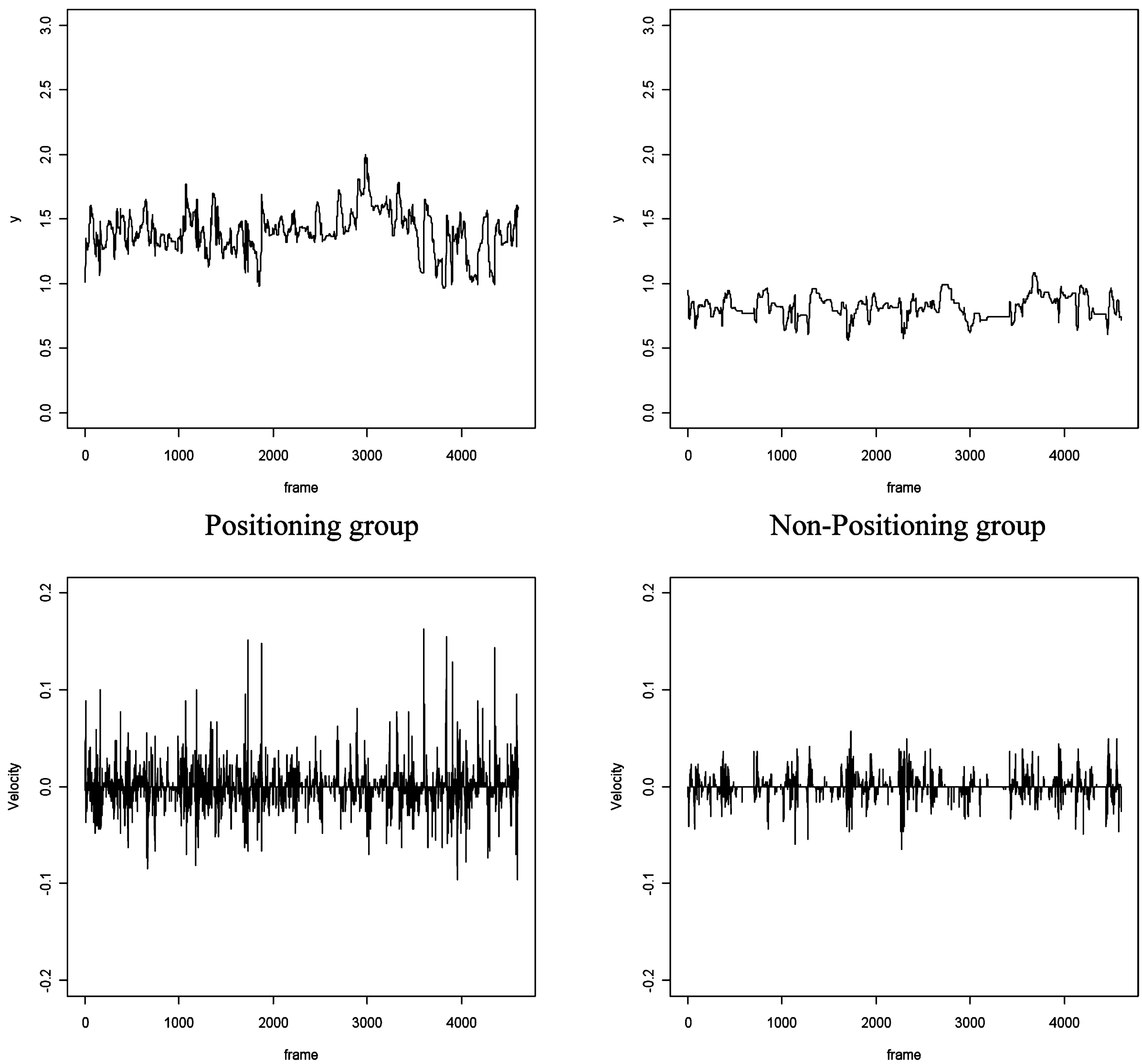


Fig. 4. Example time series and velocity plots of the right foot y.
Upper panels show time series of right foot y values of two infants (one each from the positioning group and the non-positioning group, respectively). Lower panels show the velocity plots of the right foot y values corresponding to the upper panels. These panels show that the variations in the velocity of right foot were greater in the positioning group than in the non-positioning group.

infants achieves the following. First, it reduces excessive unstable movements of infants and enables them to assume stable postures by providing tactile sensibility as well as a sense of pressure throughout the body. Second, it facilitates self-quieting activities by providing opportunities for infants to bring their hands to the midline. Third, it facilitates the development of sensorimotor experiences and promotes neuronal maturation since infants interact with their environment through their own activities. Positioning has been employed in developmental care[23–25] using the swaddling and nesting technique, and there are some studies reporting the effects of these techniques[26–30]. However, most of the research has focused on developmental care as a whole and little is known about the effect of the positioning technique on the movement patterns of very low-birth-weight infants.

In some previous studies of the positioning technique, preterm infants showed improved neuromuscular development when swaddled[31], less physiological distress, better motor organization, and better self-regulatory ability when swaddled during weighing[32]. Also, regular changes in posture allowed maintenance of normal neuromuscular and osteo-articular function, and permitted the development of spontaneous and functional motor activity in low-risk preterm infants[33]. Supine positioning of infants in a hammock was associated with a higher neuromuscular maturity score along with better relaxation[34]. De Graaf-Peters et al. reported that specific postural support promoted the variation in motor behaviour of young infants. In particular, the movement repertoire was increased by supporting the infant with a specific pillow in the infants with multiple neurological dysfunctions (MND)[35]. Ferrari et al. evaluated the posture and spontaneous movements of healthy preterm infants in and out of the nest. They reported that nest-like support promoted a flexed and adducted posture of the limbs and facilitated movements toward and across the midline[36].

In our study, we focused on the spontaneous movement patterns of infants who received the positioning program in the NICU. We quantitatively investigated how the positioning program influenced their movement patterns for as long as 1 month after the positioning program was terminated. The infants in the positioning group exhibited a pattern of movements similar to that of full-term infants. This suggests that appropriate positioning of preterm infants facilitates flexion postures and the development of antigravity activity. The infants in the positioning group learned movement patterns, involving movements toward the centre of the body, similar to foetuses in the uterus. They also learned better movement organization. This indicates that the positioning program had some influence on spontaneous movements from the viewpoint of interaction of the infant with the environment, and it also facilitated the development of sensorimotor activity in preterm infants. In fact, moving in the restricted space of the positioning wall facilitated arm and leg movements which allow the infant to touch various parts of their bodies. This means that they also acquired opportunities to integrate tactile and proprioceptive sensibilities. The benefits of the positioning program on central nervous system maturation are still under investigation, and we require a longitudinal follow up on the effect of positioning on preterm infants.

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