ANALYSIS OF THE MECHANISMS DETERMINING THE RATE OF INFLATION OF THE LUNGS AFTER BIRTH

(UDC 612.216.2:612.648)

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Translated from Byulleten' Éksperimental'noi Biologii i Meditsiny, Vol. 61, No. 3, pp. 24-28, March, 1966
Original article submitted May 13, 1965

Conflicting solutions have been given to the problem of the rate of aeration of the lungs from the moment a newborn infant leads an independent existence. Some authors report that the pneumatization of the lungs, starting soon after separation of the cord, takes place gradually during the first and second weeks of life [4,6, 11, 13]. Others claim that the lungs fill with air soon after the first extrauterine respirations [5, 7-10, 12, 14, 15] or within the first hour [3]. These different opinions are explained by the inadequacy of the data concerning the physiological mechanism of the first extrauterine respirations and the significance of the degree of physiological maturity of the newborn infants in this process.

The object of the present investigation was to study by means of roentgenography the rate of aeration of the lungs in newborn animals after natural birth and also in experimental conditions after division of the umbilical cord of fetuses extracted by caesarian section.

EXPERIMENTAL METHOD

Observations were made on newborn and fetal cats (43), dogs (12), and rabbits (62).

Caesarian section was performed on the pregnant rabbits without anesthesia, on the cats under ether anesthesia (sometimes with the addition of urethane), and on the dog under morphine and ether anesthesia. In some experiments a state of fetal hypoxia was created similar to intrauterine, by extracting the whole fertilized ovum from the uterus and rupturing its membranes after 3, 5, 7, 10, and 12 min. In other experiments intrauterine asphyxia was obtained by extracting the fetuses at the same intervals after sacrifice of the pregnant female. Survey roentgenography, often serial, of the animals born by caesarian section or as a result of natural parturition was carried out at various times after birth—from 1 min to 11 days. Altogether more than 900 roentgenograms were studied. The roentgenological picture of the lungs was evaluated in accordance with the type of respiration and the physiological state of the newborn animals.

EXPERIMENTAL RESULTS

The investigations of I. A. Arshavskii showed that three types of respiration should be distinguished during the analysis of the change from intrauterine respiratory movements to extrauterine [1, 2]. The first corresponds to the intrauterine respiratory movements with the character of gasps; the second to the first extrauterine respirations of the apneusis type; the third to established extrauterine respiration of pneumotaxic character. The results of these investigations showed that intrauterine respiration of gasping type is under bulbar regulation. In fetuses joined to the mother through the umbilical cord, during intrauterine respiratory movements of gasping character, even in experimental conditions when the respiratory orifices of the fetus were in contact with air, no air was aspirated into the lungs [1, 2].

Extrauterine respiratory movements characteristic of apneusis, starting after separation of the fetus from the mother, takes place as a result of the bringing into play of the metencephalic link of the respiratory center in the

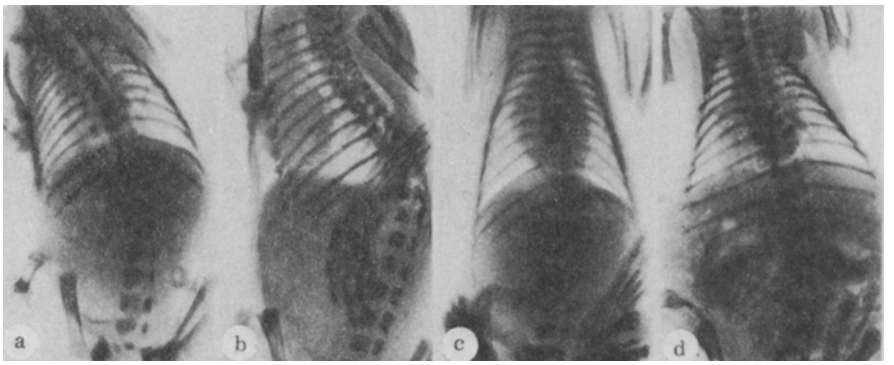

Fig. 1. Aeration of the lungs of three physiologically mature kittens born naturally at term. a) At the first minute in the phase of inspiration the lungs are largely pneumatized, but the heart shadow is not yet contrasted; b and c) beginning and end of second minute from beginning of respiration in another kitten; borders of the diaphragm and heart are clear not only at the beginning of inspiration (b), but also during expiration (c): the degree of transparency of the lungs is indistinguishable from that in a 4-day old kitten in the resting state (d).

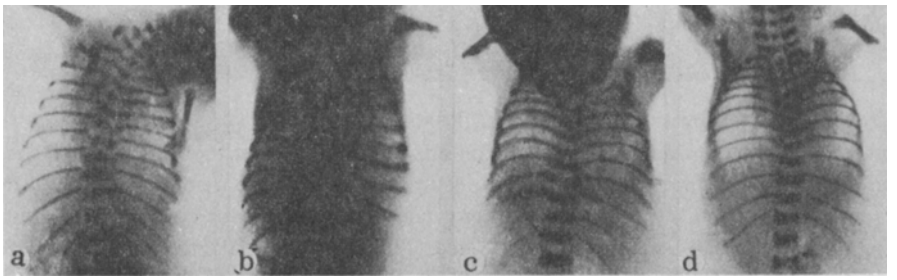

Fig. 2. Premature viable rabbit extracted by caesarian section. First 5-7 min after birth. The lower lobes of the lungs are not yet aerated, the border of the diaphragm cannot be defined. The remainder of the lung tissue is feebly aerated. During inspiration areation is intensified and the heart shadow becomes visible (b and d); during expiration de-aeration takes place and the heart shadow becomes indistinguishable (a and c).

process of regulation [1]. In physiologically mature fetuses (kittens), born naturally, the first fully effective extrauterine respiratory movements of apneusis type appear from the roentgenological picture to produce almost total aeration of the lungs (Fig. 1).

Some of the details of the mechanism of aeration of the lungs during the first extrauterine respiratory movements of apneusis type are clearly seen in the premature, but physiologically mature fetuses of rabbits extracted from the uterus by caesarian section without anesthesia several days before natural parturition. Because of the somewhat slower tempo of aeration of the lungs the first respirations of apneusis type were characterized roentgenologically by considerable deaeration of the lungs during expiration (Fig. 2). During respirations apneusis type began to develop gradually in the thorax not only during inspiration, but also during expiration (static depression).

If the fetuses were physiologically mature, their respiration quickly changed from the apneusis type to the pneumotaxic, as a result of inclusion of the superior portion of the metencephalon and the mesencephalic link of the respiratory center in the regulatory function [1]. In pneumotaxic respiration static depression and complete aeration of the lungs were finally established, as shown by the roentgenological picture, in which the lungs in expiration remained almost as transparent as during inspiration (Fig. 1).

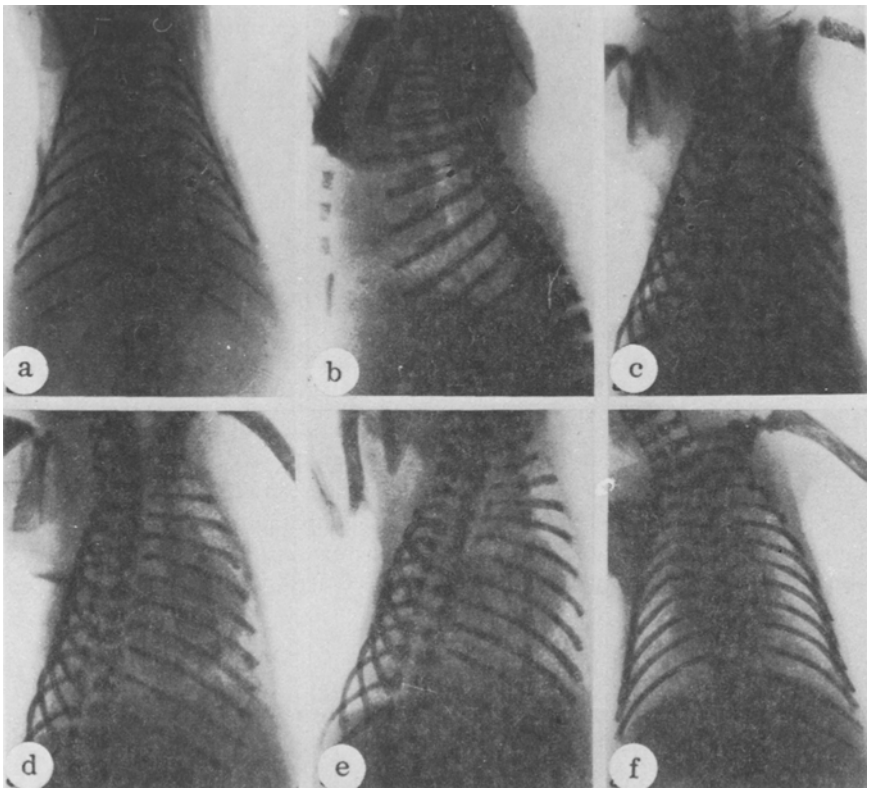

Fig. 3. Kitten extracted by ceasarian section. Ether anesthesia. Overdose. During the second inspiration in apneusis considerable de-aeration appeared, so that at the beginning of the third inspiration (c) the lungs appear only slightly pneumatized by comparison with the state of apnea (a). After 5 (c) and 20 (d) min the lungs gradually became more transparent. During inspiration (e) 4 h after birth the outlines of the heart shadow were still indistinct because of the inadequate aeration of the central portions.

In physiologically mature newborn animals, in connection with the transition to pneumotaxic respiration total aeration of the lungs, determined roentgenologically, was established during the first minute (in the rabbits) or within 1-2 min (in kittens).

The rapid transition to efficient pneumotaxic respiration was combined with the simultaneous appearance of tone in the skeletal muscles, the appearance of motor activity, and the establishment of an adequate level of heat production, as shown by the rapid drying of the skin and hair.

In the very immature but viable fetuses extracted from the uterus by caesarian section, the transition to normal pneumotaxic respiration sometimes lasted for several hours as a result of a prolongation of the period of apneusis, and frequently also as a result of the appearance of an additional period of imperfect pneumotaxic respiration, preceding the normal pneumotaxic respiration. The imperfect pneumotaxic respiration was distinguished outwardly by its slower rhythm than normal. It was usually combined with the absence of drying of the hair during this period and a lower body temperature, reflecting the inadequate level of heat production.

Corresponding to these features distinguishing the transition ot extrauterine respiration, the process of aeration of the lungs as determined roentgenologically was slower and irregular. The aeration of the lungs did not immediately reach the level at which static depression can develop, and when this did take place its degree fluctuated along with the changes in the tone of the skeletal muscles: during temporary relaxation of the tone a marked de-aeration of the lungs took place in expiration, despite its passive character. In the rabbits the basal portions, and in the kittens the apical portions of the lungs filled slowly with air. In the period of imperfect pneumotaxic respiration, when

the muscles tone became constant and static depression was gradually established, the lungs were not finally pneumatized in their central and hilar portions.

The delayed pneumatization of the lungs in the immature yet viable fetuses was evidently due to the lower amplitude of the respiratory movements in apneusis as a result of the incompleteness of morphological and physiological development, primarily to the neural mechanisms and the system of the respiratory organs.

A transition to pneumotaxic respiration prolonged on account of the imperfection of the first respirations in apneusis were also observed in newborn animals born at term but physiologically immature. The delayed appearance of tone in the skeletal muscles and the longer period of apneusis were combined in these animals with a slowly developing aeration of the parenchyma of the lungs.

Anesthesia of the mother and artificial intrauterine asphyxia of the fetus had an inhibitory action on the speed of the transition to perfect extrauterine respiration. This action was proportional to the depth of anesthesia or asphyxia. After superficial anesthesia, the periods of apnea and apneusis were prolonged, the establishment of the tone of the skeletal muscle and of static depression was delayed, and the process of aeration of the lungs took place correspondingly more slowly. With deep anesthesia, especially if combined with intrauterine hypoxia, the respiration of apneusis type beginning after a longer period of apnea at first had a slower rate and smaller amplitude, because the filling of the respiratory passages with air increased only gradually, with each inspiration. The aeration of the parenchyma of the lungs in these circumstances took place very slowly because of the absence of adequate tone in the muscles, including the intercostals. For a long time no static depression was established, for during expiration, despite its passive character, almost complete aeration of the lungs took place at first. Gradually, as it recovered from the anesthesia, the newborn animal developed muscle tone, the expiration became active in character, as demonstrated by a cry; the static depression and aeration of the lungs increased, but for a long time (sometimes for hours) feebly aerated areas remained in their parenchyma, corresponding to the period of imperfect pneumotaxic respiration preceding the normal pneumotaxic respiration (Fig. 3).

Hence, the rate of aeration of the lungs after birth, as recorded roentgenologically, may vary between wide limits (in these experiments from 1-2 min to several hours) depending on the intrauterine age of the fetus and the physiological maturity and condition of the nerve centers.

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