Acta Paediatrica Academiae Scientiarum Hungaricae, Vol. 17 (3), pp. 219—225 (1976)

Idiopathic respiratory distress syndrome: acoustic, laryngoscopic and radiological investigation

By

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(Received 7 March, 1976)

The breathing pattern in IRDS has been analysed by sound recording, direct laryngoscopy and chest X-rays. The reflex mechanism operative in IRDS was found to be a modified version of the Hering-Breuer reflex; in a certain phase of inspiration the respiratory muscles relax and passive expiration begins. In IRDS, at the end of the short inspiratory phase accompanied by grunting the glottis is suddenly closed, and collapse of the alveolar space is prevented. The small opening of the glottis before the next inspiration serves the same purpose, and the air passing through it is heard as grunting. As soon as the alveolar space is emptied, the glottis becomes wide open and a quick inspiration follows.

The modified Hering-Breuer reflex increases the respiratory tract pressure and thus prevents collapse of the alveolar space. When the newborn is no longer capable of the excess extra work required for grunting, the decompensated phase of IRDS sets in. Gas exchange rapidly deteriorates and the white lung pattern is visible on the chest X-ray.

Certain patterns of crying in the newborn have long been associated with pathological conditions such as brain damage, Down syndrome, etc. Analysing the sound forms it was found that sound frequency recordings offer a reliable diagnostic tool, but only acoustic investigations based on frequency analysis can differentiate between various pathological conditions. Individual cycles of respiration, the ratio between inspiration and expiration, cannot be recorded by this approach.

In order to characterize the irregular breathing in the idiopathic respiratory distress syndrome (IRDS) of the newborn, sound recordings are needed that give information on the frequency of breathing, the exact ratio of inspiration and expiration and the localization of grunting in the respiratory cycle. With this aim, phonorespiratography (PRG) was performed in newborns affected by IRDS. The method allowed an exact recording and analysis of inspiration and expiration and of the typical sound patterns that characterized the IRDS.

Since PRG records audible sounds, its importance lies in the following points.

a) PRG allows to record the time-course of events. The ratio of inspiration and expiration can be determined.

b) By analysing the time-course, normal and abnormal breathing patterns can be established. Respiratory problems can be differentiated on the basis of their PRG curves.

c) PRG records can be stored and thus comparisons with previous curves can be made. Longitudinal studies can be registered graphically.

d) By recording and analysing the time-course it is possible to plan the ventilation best suited for the given condition.

Material and Method

PRG was carried out in twenty 2—12 hour old newborns with IRDS, immediately after admission, prior to the initiation of ventilation. The diagnosis of IRDS, initially made on the basis of clinical findings, was supported by examination of the acid-base balance and oxygen saturation, and by radiological investigations.

Phonorespirogram were recorded using the microphone from a phonocardiograph. The microphone was placed on the right side of the chest in the midaxillar line in the fourth intercostal space, since it was in this region that the heart sounds caused the least interference. As the aim of sound recording is to analyse the time-course of breathing, a paper speed of 50 mm/sec was used. The middle frequency range of phonocardiography was found the most suitable for PRG monitoring.

The phonorespirogram of healthy newborns

In the healthy, regularly breathing newborn the peaks corresponding to inspiration and expiration, and the silent part corresponding to the postexpiration interval are easily identified. The length of inspiration and expiration is approximately equal under normal conditions. One breathing cycle in the regularly breathing newborn takes 1.0 to 3.0 seconds. Of this, 0.5 to 1.50 seconds are needed for inspiration, and 0.5 to 1.30 seconds for expiration. Every tenth to fifteenth breathing cycle is somewhat longer than the average (Fig. 1).

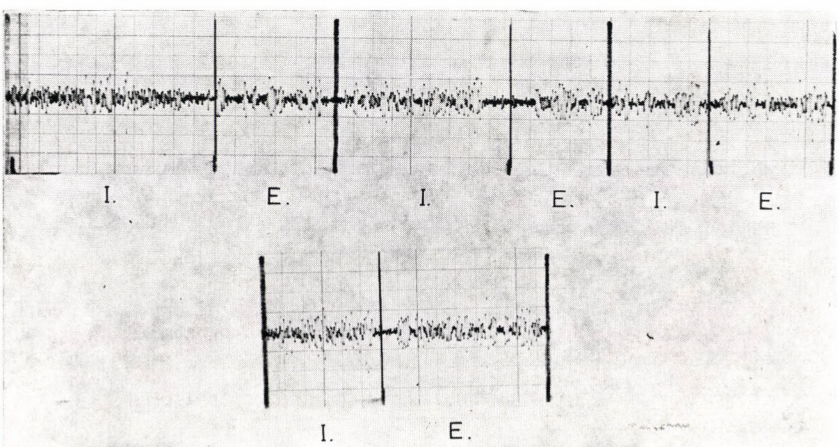

Fig. 1. Phonorespirogram of 3 hours old healthy newborn. The inspiratory and expiratory periods are identical in duration

The phonorespirogram of IRDS

The phonorespirograms of newborns affected by IRDS show considerable distortions. For their analysis the following investigations were carried out.

A) Phonorespirography of respiration accompanied by grunting.

B) Phonorespirography of respiration not accompanied by grunting.

C) Position of the glottis during respiration accompanied by grunting.

D) Radiological investigation during respiration accompanied by grunting.

E) Position of the glottis and chest X-ray of respiration not accompanied by grunting.

A) *Respiration accompanied by grunting* (Fig. 2)

The period of inspiration is significantly shorter than the period of expiration. Inspiration is followed by a silent period, then during expiration a sound form is recorded which corresponds to grunting. This phenomenon is followed without any interval by the sound form of inspiration.

B) *Respiration not accompanied by grunting* (Fig. 3)

During the tachypnoeic respiration, the inspiration is equal in length to or only slightly shorter than the expiration. There is no silent period and the acoustic picture of expiration is much shorter than that of grunting. Expiration is often followed by a silent period, which in turn is followed by an inspiration.

After the respirations accompanied by grunting, the breathing sounds are diminished and superficial panting ensues. During panting, sound forms can hardly be distinguished on the PRG.

C) *Position of the glottis during respiration accompanied by grunting*

Exposing the glottis with the aid of a McIntosh type laryngoscope, the following observations were made.

(i) During the inspiration phase, the glottis is maximally open.

(ii) During the silent phase, the glottis is completely closed.

(iii) During grunting the glottis is half-open.

(iv) During inspiration the glottis is again maximally open.

D) *Radiological examination during respiration accompanied by grunting*

Serial X-ray pictures taken simultaneously with PRG recordings showed the following (Fig. 4).

(i) The air content of the lungs increases during the inspiratory phase.

(ii) During the silent period there is no change in pulmonary air content.

(iii) Pulmonary air content diminishes quickly during the phase of grunting. At the end of this period, the X-ray pictures show a typical white lung.

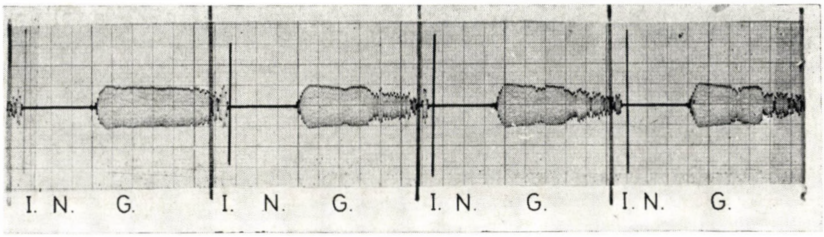

FIG. 2. Phonorespirogram of baby with RDS. Grunting appears at the end of expiration

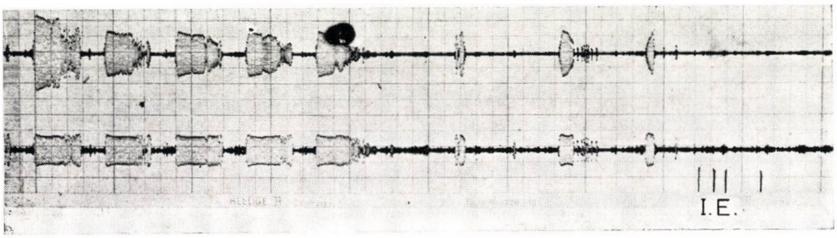

FIG. 3. Phonorespirogram, chest X-ray and picture of the vocal chords, during grunting. The chest X-ray reveals good aeration during the inspiratory phase. At the beginning of expiration, the larynx is closed and there is hardly any change in aeration. During the period of grunting, there is a rapid decrease in aeration, the vocal chords are open

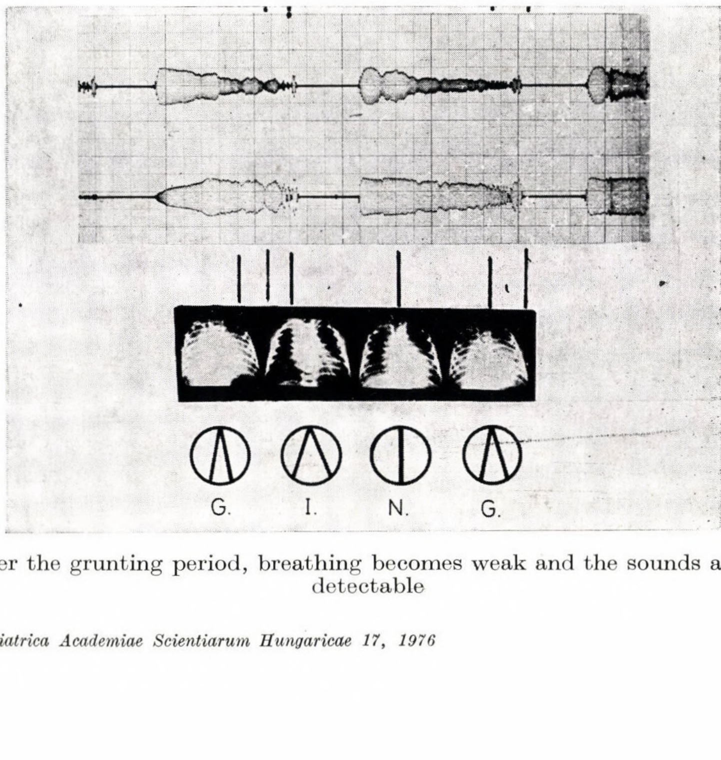

FIG. 4. After the grunting period, breathing becomes weak and the sounds are no more detectable

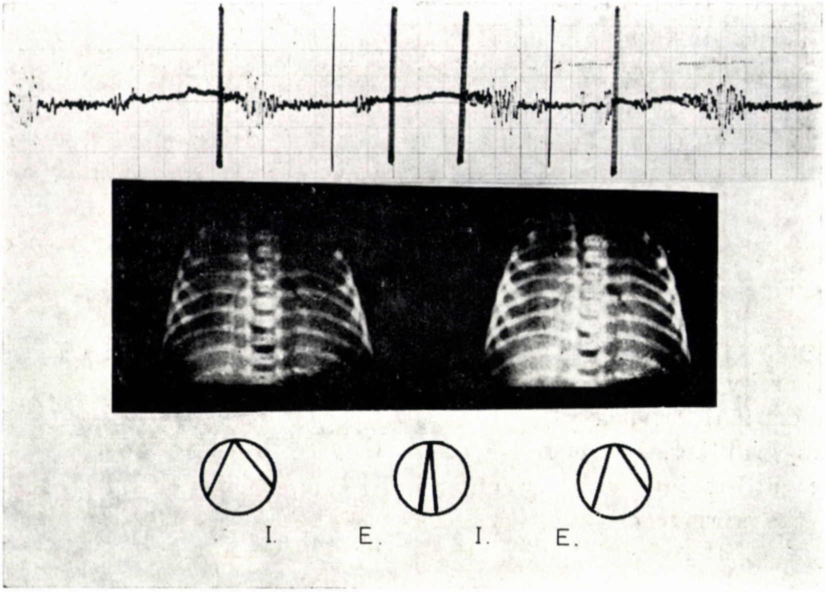

FIG. 5. Respiration without grunting. The breathing sounds diminish as the disease progresses and the lung fields become white. The movements of the vocal chords are irregular

E) *PRG, glottis position and chest X-ray during respiration not accompanied by grunting*

Simultaneously with PRG recordings, laryngoscopy was carried out during respiration not accompanied by grunting. During inspiration the glottis is maximally open, while it is slightly constricted during expiration and completely closed during the silent phase following expiration. Serial X-ray pictures show nearly equal amounts of air in the inspiratory and expiratory phases. During the tachypnoeic phase the air content gradually diminishes to disappear completely; the X-rays then show a white lung pattern. Following the next respirations accompanied by grunting, aeration of the lungs increases (Fig. 5).

Discussion

Irregular breathing in IRDS results from successive slower respirations accompanied by grunting and faster respirations not accompanied by gurnting [2, 4]. On introducing a tube into the trachea, breathing became regular, the frequency of respiration rose, but gas-exchange deteriorated. These observations suggested that a reflex mechanism functioning in IRDS was eliminated by intubation, and this led to the death of the infant. The reflex mechanism is probably a modified Hering-Breuer reflex, adopted to the neonatal period. The Hering-Breuer reflex operates when in a certain phase of inspiration transpulmonary pressure increases, leading to the relaxation of respiratory muscles and thus the commencement of expiration. According to the present findings, in IRDS the reflex is modified: it closes the glottis during expiration to prevent collapse of the alveolar space.

PRG, laryngoscopy and X-rays showed that the reflex mechanism, which results in the observed specific breathing pattern in IRDS, permits an increased aeration of the lung and thereby enhances gas-exchange. The short and forced inspiration that follows grunting, the closed glottis and retarded intra-alveolar air all serve the purpose of preventing the collapse of the alveolar space. The respiratory rate decreases during the grunting periods, owing to a prolongation of the expiratory phase. The period of inspiration, as judged from the PRG, is very short, taking not more than 0.1 to 0.3 sec. The silent period, corresponding to the closed glottis, is comparatively long, reaching 1 sec. The duration of grunting varies between 0.1 and 1.20 sec, depending on the length of the preceding inspiration. After a deep inspiration, the greater amount of air results in longer grunting, as demonstrated by the X-ray findings.

The irregularity of breathing in IRDS is due to the fact that respirations accompanied by grunting are followed by a tachypnoeic period. During this period the reflex mechanism fails to function and thus collapse of the alveolar space becomes pronounced. In the absence of the reflex mechanism gas-exchange and the newborn's condition deteriorate similarly as in the intubated IRDS patient [2].

Role and function of the reflex mechanism follow from Laplace's law concerning bubbles, and are thus valid for the alveoli, too. According to this law, the pressure exerted on the surface of the globe is directed towards the centre. Under the effect of surface tension, the globe occupies the smallest volume at which internal pressure and surface tension are equal. If the internal pressure decreases, the surface tension forces the globe to shrink but increases further when the radius of the globe decreases. The formula is $P = \frac{2\,ST}{R}$, where P = the pressure exerted on the wall of the globe; ST = the surface tension measured at the gas-fluid interface; and R = the radius of the globe.

The alveoli measure 40 μ in diameter, their surface tension is 55 dine/cm. The internal pressure diminishes towards the end of expiration, as the air leaves freely through the alveolar ducts. It follows that the alveolar space is prone to collapse, and without counter-action it will definitely do so.

The newborn's first inspiration occurs at a transpulmonary pressure of 70 cm H_2O. This high pressure ensures satisfactory aeration by counteracting the surface tension. The individual alveoli become extended, their diameter increases. With the increase of the alveolar radius, surface tension decreases. In the absence of surfactant, the newborn is forced to repeat the great task of the inspiration through several hours, as the increased surface tension causes the alveoli to collapse during each expiration.

During expiration, surface tension becomes again the decisive factor and the alveolar space becomes deflated. The newborn defends himself against this process by automatically closing his glottis after every inspiration. The closed glottis prevents alveolar collapse as the pressure of air retained in the respiratory tract and the alveolar space are in equilibrium with the surface tension. Before the next inspiration, however, the glottis opens and the alveolar space collapses. With the aid of the modified Hering-Breuer reflex, the newborn attempts to maintain an increased respiratory tract pressure to prevent collapse of the alveoli.

Similarly to the reflex mechanism, the aim of artificial ventilation is to achieve a long-term increase in respiratory tract pressure. After loss of the reflex mechanism, when the newborn is no longer capable of exerting the effort necessary for the respirations accompanied by grunting, the decompensated phase of IRDS sets in. Gas exchange at this stage shows rapid deterioration and the so-called white lung pattern appears on the X-ray picture.

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