J. Physiol. (1943) 102, 88–94 612.21

PERIODIC CHANGES IN RESPIRATORY DEPTH, PRODUCED BY CHANGES IN THE LUNG

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(*Received* 23 *December* 1942)

It is generally assumed that periodic changes in respiratory depth are produced by periodic alterations in the activity of the respiratory centre. It is the purpose of this communication to show that periodic breathing may in some cases be caused by periodic changes in the distensibility of the lungs, without any changes in the activity of the respiratory centre.

Methods

It has been shown by Christie & McIntosh [1934] that changes in the distensibility of the lungs can be measured *in vivo* by means of simultaneous recordings of the tidal air and intrapleural pressure. The fall in pleural pressure which occurs on inspiration represents the force exerted in the lungs by the respiratory muscles, and the tidal air the expansion which results. Any increase in the activity of the respiratory centre will increase respiratory effort, and will therefore increase both the pleural pressure fluctuation and the tidal air. Changes in the distensibility of the lungs, however, will not produce any change in the pleural pressure; they will only produce a corresponding change in the tidal air. From such a record, therefore, it is possible to distinguish changes in respiratory depth due to changes in the activity of the respiratory centre from those due to changes in the distensibility of the lung. The validity of this method of measuring the distensibility of the lung *in vivo* has been established by several investigators, and is an essential part of this communication [Paine 1940; Christie, 1934; Christie & Meakins, 1934].

Observations have been made on fifteen animals—mostly cats—in which periodic breathing occurred. The technique of measuring and recording the pleural pressure fluctuation by means of a water manometer has been previously described, and the tidal air was recorded using a closed circuit chain counterbalanced recording spirometer with mercury cap valves [Christie & McIntosh, 1934]. The resistance of the circuit with the animal breathing quietly was 2–4 mm. H_2O. All animals were breathing 100% oxygen during the whole of the experiment. Three typical experiments are described.

Results

In Fig. 1 the periodic waxing and waning of the tidal air is well shown, but the pleural pressure fluctuations remain unaltered during this period. The force exerted on the lungs thus remains constant, but the tidal air varies, and this must be interpreted as being due to a periodic change in the distensibility of the lungs and not to any change in the activity of the respiratory centre. The contrast between this type of respiratory change and that produced by alterations in the discharges from the respiratory centre is shown also in this tracing. At *A*, the animal takes a few irregular breaths, as shown in the tidal air tracing,

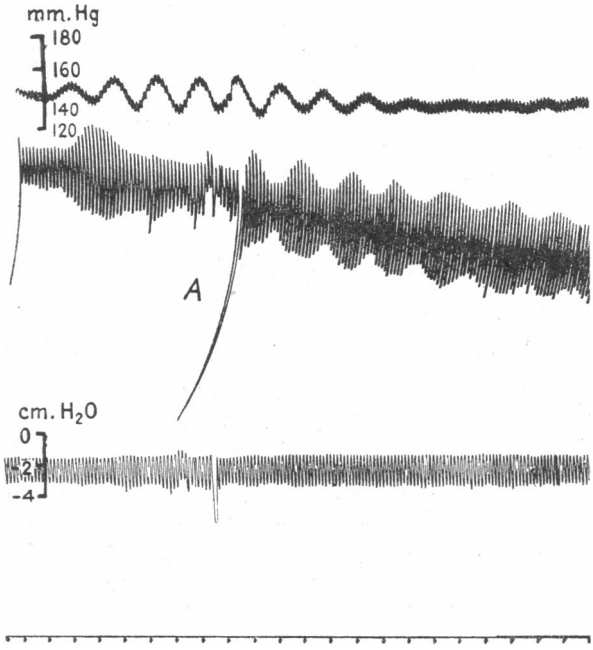

Fig. 1. Cat 52. 5·25 kg. Intraperitoneal dial 45 mg./kg. Upper tracing, blood pressure; middle tracing, tidal air; lower tracing, pleural pressure fluctuation. Time marker, 10 sec. Spontaneous periodic breathing as soon as animal was anaesthetized. Periodic variations in tidal air with no change in the pleural pressure fluctuation.

and there is a corresponding alteration in the pleural pressure fluctuation. The blood-pressure record shows Traube-Hering waves of the same periodicity as the tidal-air variations. Periodic breathing, however, persists when Traube-Hering waves are hardly visible, so that the respiratory changes do not appear to be secondary to the changes in blood pressure.

Fig. 2 also shows a marked fluctuation in the tidal air, this time of longer cycle, but again there is no change in the pleural pressure fluctuations. In this animal the blood pressure remained unaltered during the period of variation in respiratory depth.

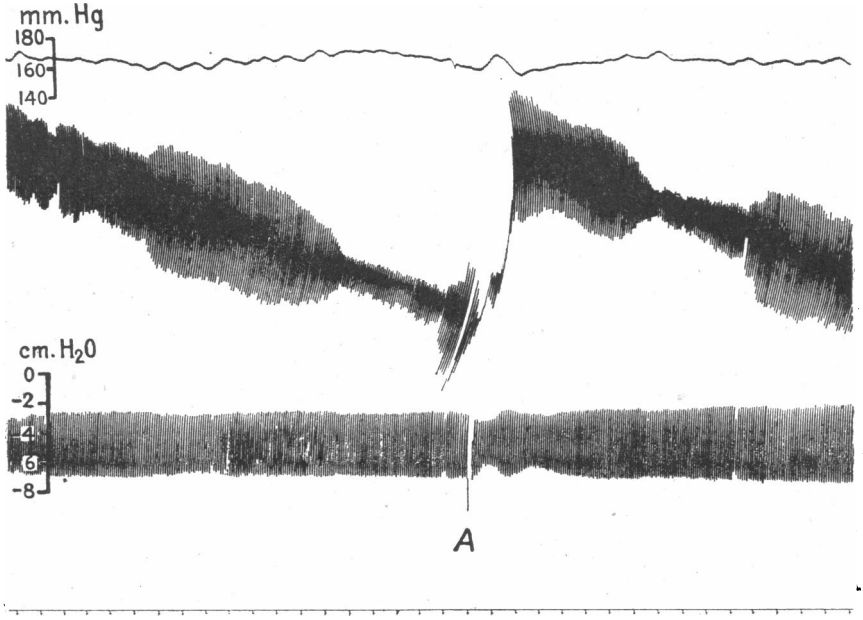

Fig. 2. Cat 51. 4·5 kg. Intraperitoneal dial 45 mg./kg. Tracings as in Fig. 1. Spontaneous periodic breathing without change in the pleural pressure fluctuation. At *A*, spirometer refilled.

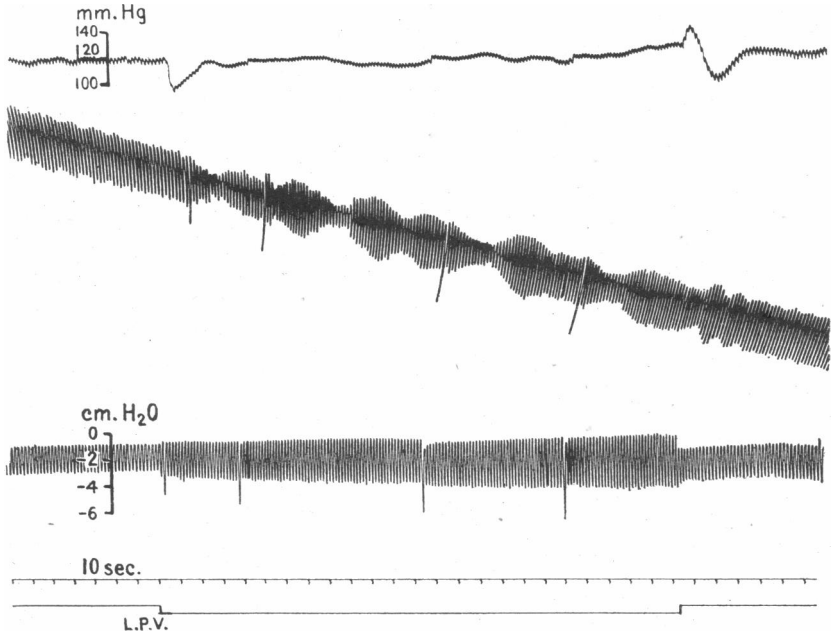

Fig. 3. Cat 50. 3·25 kg. Intraperitoneal dial 50 mg./kg. Tracings as in Fig. 1. Drinker heart preparation, with loose ligatures around the left pulmonary veins. Periodic breathing produced by occlusion of these veins (*L.P.V.*). Gradual slight increase in pleural pressure fluctuation. Normal breathing and return of pleural pressure fluctuations to their initial values when the pulmonary circulation was restored.

Fig. 3 is a tracing obtained from a Drinker heart preparation in the cat [Drinker, 1921]. An elliptical window was cut in the anterior chest wall over the heart, and the pleural cavities were closed by stitching the reflected pericardium to the margins of the window. The left pulmonary veins were exposed at their junction with the left auricle, and a ligature was put loosely around them so that gentle traction would cause occlusion of the veins. The effects of

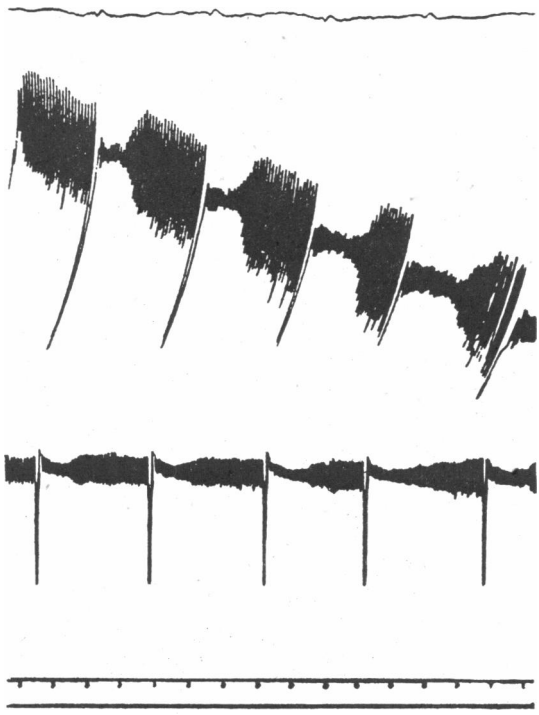

Fig. 4. Cat 58. 5 kg. Intraperitoneal dial 45 mg./kg. Tracings as in Fig. 1. Periodic breathing due to periodic changes in the activity of the respiratory centre. Changes in respiratory depth are associated with corresponding changes in pleural pressure.

occlusion of the pulmonary veins are shown in Fig. 3. After occlusion, a well-marked waxing and waning of the tidal air appears, without a corresponding change in the pleural pressure fluctuation, although both are seen to increase when the animal takes an occasional deep breath. There is a gradual slight increase in the pleural pressure fluctuation when the left pulmonary veins are occluded, but when the pulmonary circulation is restored breathing becomes regular again and the pleural pressure fluctuation returns to its initial value.

The contrast between this type of periodic breathing and the central type with altering activity of the respiratory centre is well shown in Fig. 4. Here the tidal air and pleural pressure vary together.

In all, fifteen animals (twelve cats and three rabbits) showing periodic breathing were studied in this investigation. Eleven showed the type of periodic breathing illustrated in Figs. 1–3. Four showed the type of breathing in Fig. 4. The periodic breathing arose spontaneously, either as soon as the animals were anaesthetized or, more often, at the end of some other experiment when the cardiovascular system was in poor condition.

Discussion

These findings may be discussed (*a*) in terms of pulmonary dynamics, and (*b*) in their relationship to human periodic breathing (Cheyne-Stokes breathing). The type of periodic breathing described, with well-marked changes in tidal air and yet a constant fluctuation in pleural pressure, cannot be of central origin, since any changes in the intensity of the nervous discharges from the respiratory centre must be associated with increased respiratory effort and comparable changes in the pleural pressure readings. It must be due to some changes in the lung itself, whereby the same force exerted on the lung causes a varying amount of expansion. In other words, there is a periodic change in the distensibility of the lung. It appears almost certain that the cause of this change is a variation in the degree of pulmonary congestion. It is improbable that the change was due to broncho-spasm, as in six experiments adrenalin did not abolish the periodicity and there was no evidence of respiratory obstruction. Furthermore, the normal response to respiratory obstruction is an immediate increase in respiratory effort, and this did not occur [Christie, 1938].

It is known that the pulmonary vessels are supplied by sympathetic and parasympathetic nerves, and a periodic alteration in the discharges from the pulmonary vasomotor centre could, in this case, account for the respiratory changes. Fig. 1 is interesting in this respect, as Traube-Hering waves in the systemic circulation are associated with periodic breathing of the same frequency, suggesting that the same periodic alterations in the degree of vascular tone may take place in the pulmonary circuit.

Periodic variation in the tone of the pulmonary vessels has occasionally been noted in lung-perfusion experiments, but no observations on tidal air were made [Daly, Ludány, Todd & Verney, 1937]. In Fig. 3 periodic breathing was initiated each time one set of pulmonary veins was occluded, which also suggests that some alteration in the pulmonary circulation is responsible for the periodic breathing.

It has been established that the periodic breathing due to anoxaemia or depression of the respiratory centre differs in several respects from that seen in cardiovascular disease. In the former, the blood pressure rises during apnoea and falls during hyperpnoea, whereas in the latter exactly the reverse takes place [Eyster, 1906]. In cardiovascular disease, the duration of the cycle is usually much longer and there is a fluctuation in the respiratory level which

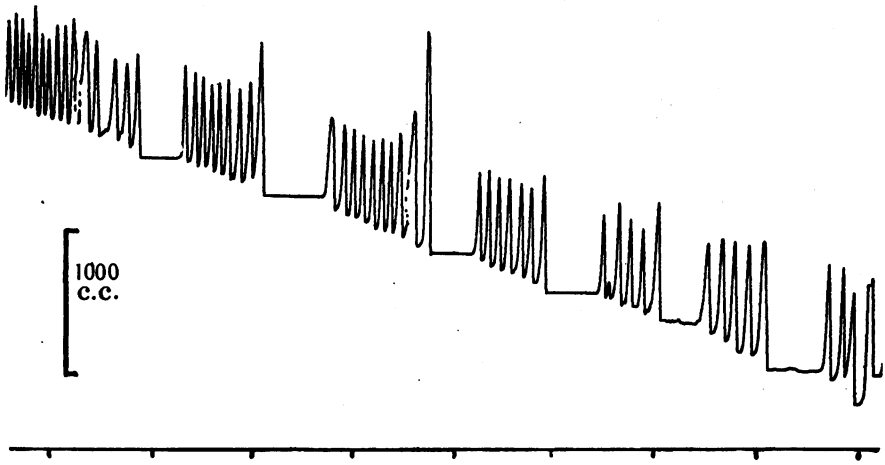

Fig. 5. Periodic breathing in a patient suffering from acute codeine poisoning. The patient was breathing pure oxygen from a spirometer and the tracing reads from right to left. Periodicity tends to diminish with oxygen and there is no fluctuation in respiratory level. Time signal, 1 min.

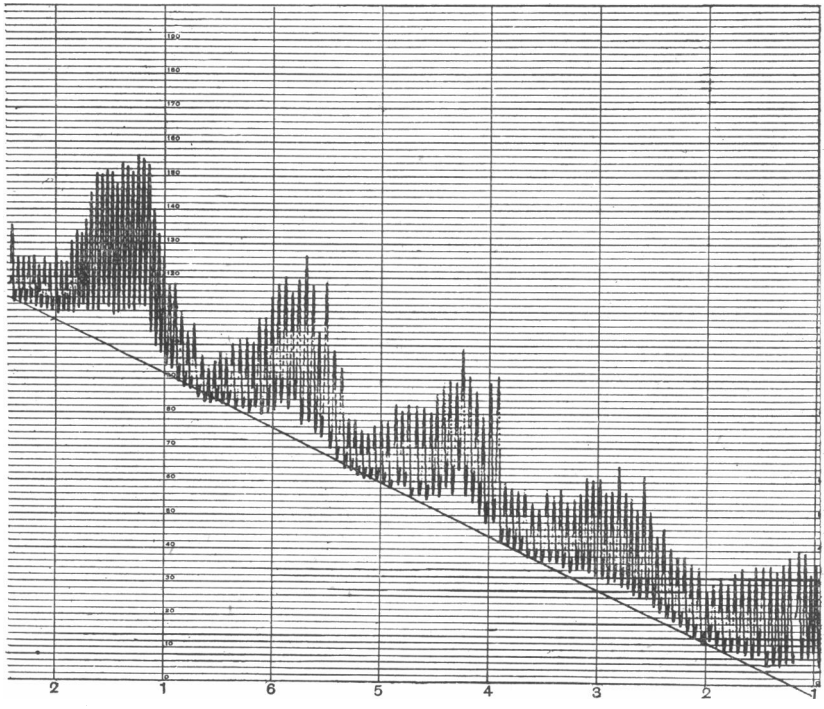

Fig. 6. Periodic breathing in a patient suffering from hypertension and heart failure. The patient was breathing pure oxygen from a spirometer and the tracing reads from right to left. Periodicity tends to increase with oxygen and there is a marked fluctuation in respiratory level. Distance between heavy horizontal lines represents 209 c.c. Vertical lines at intervals of 1 min.

does not occur in Cheyne-Stokes breathing due to cerebral causes [Green, 1933] (Figs. 5 and 6). The response to oxygen therapy also serves to separate the two types. In the cerebral type oxygen usually abolishes Cheyne-Stokes breathing, whereas in the cardiovascular type oxygen usually produces either no change or may exaggerate the periodicity [Green, 1933] (Figs. 5 and 6).

These differences cast doubt on the usual physiological explanation of the mechanism of Cheyne-Stokes breathing, based almost entirely on experiments with anoxia. The mechanism of Cheyne-Stokes breathing in cardiovascular disease may be fundamentally different, and it seems possible that the fluctuations in respiratory depth associated with an alteration in respiratory level may be due, in part at least, to a periodic alteration in the degree of pulmonary congestion.

There is thus a possible relationship between the types of periodic breathing we have described in animals, and which we interpret as being caused by a waxing and waning pulmonary congestion, and the type of periodic breathing seen clinically in patients with cardiovascular disease. There are certain differences, however, which must be noted. The alterations in respiratory level which are characteristic of spirometer tracings in Cheyne-Stokes breathing in the cardiovascular group have not been shown in any of the animals. In cardiovascular disease, the administration of 5% CO_2 in oxygen, or 'euphyllin' (theophyllin and ethylenediamine) intravenously, usually abolishes Cheyne-Stokes breathing, whereas, in these animals, carbon dioxide merely increased the hyperpnoea, and 'euphyllin' (theophyllin and ethylenediamine) was without effect.

Summary

Periodic changes in respiratory depth may occur in anaesthetized animals, which are due to changes in the distensibility of the lung and not to any change in the activity of the respiratory centre.

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