Electromyogram of Respiratory Muscles Registered in the Ordinary Electrocardiogram*

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Extracardiac artefacts in electrocardiographic tracings are usually dismissed as nuisances. It is the purpose of this paper to draw attention to a phenomenon of extracardiac origin which has proved to be useful in the evaluation of the clinical state of certain patients, and to emphasize the relative frequency with which it is found when sought.

INVESTIGATION

Among the 14,000 electrocardiographic records of in-patients treated in the general hospital of the rural Emek region in northern Israel from June 1961, when we became aware of the phenomenon, until the end of 1965, the electrocardiograms of 99 patients presented the following features (Fig. 1-7):

At more or less regular intervals series of minute oscillations appeared for periods of about half a second; their amplitudes varied from 0.1 to 0.2 mV. The frequency was not quite uniform and varied from 35 to 50 per second. In a proportion of cases each series of minute oscillations was immediately preceded by one larger deflection superficially resembling a P wave of sinus origin (marked x in Fig. 3, upper strip). In one case it attained the height of 0.5 mV (Fig. 4).

The oscillations occupied no fixed position within the cardiac cycle and appeared without relation to the heart rhythm, whether the latter was regular or not; they were not abolished or substantially modified when a change in the cardiac rhythm supervened (Fig. 5 and 7). By contrast, the oscillations appeared synchronously with inspiration as determined by auscultation (Fig. 1), by inspection of the thorax (Fig. 3, 5, 6), or by comparison with the respiratory waves of the baseline of the electrocardiogram (Fig. 3, 5). In all cases in which the

conventional leads were examined the phenomenon could be observed clearly only in leads II, III, and AVF (Fig. 2). It was also recorded in the oesophageal lead of the case in which this lead was employed. Here the initial deflection appeared inverted, and all deflections belonging to the phenomenon were of the same low amplitude as those of the conventional leads (Fig. 3, middle strip).

Thus it follows that our findings are similar to or identical with those reported by Vill (1949), by Gomes Marques (1960), by Deliyannis and Salama (1965), and by Higgins, Phillips, and Sumner (1966), all of whom emphasized the connexion between the deflections seen in the electrocardiogram and respiration. There is also a striking resemblance between these deflections and those illustrated by Deitz and his associates (1957) but interpreted differently. For reasons still to be discussed, we shall refer to the deflections seen in our cases as comprising the electromyogram of respiratory muscle.

The respiratory electromyogram is easily differentiated from other cardiographic artefacts to which it bears a superficial resemblance, such as those produced by body tremor or by alternating current. The tracing between one sequence of respiratory electromyogram oscillations and the next is relatively smooth, whereas the oscillations due to body tremor and AC current are continuous. Furthermore, in the conventional cardiogram the electromyogram is restricted to leads II, III, and AVF, which is not true of the other disturbances. Body tremor oscillations are either grossly irregular or much slower than those of the respiratory electromyogram, corresponding to the frequency of somatic muscle contractions, as in Parkinson's disease. On the other hand, AC oscillations are absolutely regular. The differences between them and the respiratory electromyogram oscillations with respect to regularity, frequency, and continuity are best

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FIG. 1.—A 58-year-old woman with secondary pleural carcinoma. The simultaneous record of the inspiratory bruit heard over the right chest, and the electrocardiogram, lead II, taken 8 days before death, shows the initial “P-like” deflections and the minute oscillations characteristic of the respiratory electromyogram in synchronization with inspiration. (The upper and lower strips are continuous and have been divided for convenience of reproduction.)

seen in tracings showing the two phenomena side by side (Fig. 3, bottom strip). Even if the electrocardiogram is marred by alternating current interference in a given lead, the beginning and the end of each sequence of respiratory electromyogram are clearly defined (Fig. 7).

The respiratory electromyogram must also be distinguished from disturbance of the electrocardiogram, which can accompany a variety of abnormal—spontaneous and extraneously induced—diaphragmatic contractions (Bellet, 1963). Hiccough (Katz and Pick, 1956; Cheng and Miller, 1953), tic (Dressler and Kleinfeld, 1954), clonus (Söderström, 1950), flutter (Baker and Batty Shaw, 1951; Rigatto and De Medeiros, 1962), and diaphragmatic contractions linked to the heart beat (Söderström, 1950; Lepeschkin, 1954; Sjoerdsma and Gaynor, 1954; Frye and Braunwald, 1960) belong to this group of phenomena. The respiratory electromyogram differs from them in its strict synchronization with the respiratory cycle.

From the beginning of our observations we were impressed by the relatively frequent occurrence of the respiratory electromyogram and by the serious condition of the patients who exhibited it. All of them suffered from severe respiratory distress, whe-

ther due to cardiac, pulmonary, or metabolic disease, or to airway obstruction. In the course of time we learned to recognize the seriousness of some clinical conditions by a glance at the electrocardiogram. The principal diagnoses of the patients who exhibited the respiratory electromyogram in the different age-groups are summarized in the Table. The numbers of fatalities in every category are given in brackets.

Of our 99 patients ranging in age from 1 day to 87 years, 64 died within a short time after the respiratory electromyogram appeared in their electrocardiogram. The mortality appeared to be highest in the first month of life and among the aged. No death occurred in the 6 patients who exhibited the respiratory electromyogram during attacks of bronchial asthma. In contrast to an earlier statement (Vill, 1949), the pathology was not limited to pleural adhesions but covered a wide range of conditions.

DISCUSSION

In a recent paper Scherf and Cohen (1966) summarized the arguments which, in their opinion, militate against the interpretation of the oscillations

FIG. 2.—An 80-year-old man with chronic bronchitis and arteriosclerotic heart disease leading to congestive heart failure. Electrocardiogram taken 6 days before death shows the respiratory electromyogram deflections only in leads II, III, and AVF. They reveal no relation to the heart rhythm, which is disturbed by atrial premature beats.

in question as being due to action potentials of respiratory muscle. On the other hand, Higgins and his associates (1966) critically reviewed the recently reported tracings purporting to illustrate the phenomenon of atrial dissociation, and came to the conclusion that the majority have to be considered as examples of the "respiratory artefacts" described by the authors. With respect to our own cases we find ourselves in substantial agreement with the views of Higgins and his associates.

Our experience seems to us to present convincing

evidence for the concept of a causal link between the electrical activity of respiratory muscles and the cardiographic deflections described in the present paper. The following points substantiate our conclusions.

(a) The synchronization of inspiration with the observed cardiographic oscillations was confirmed whenever tested.

(b) In our cases, as in those of others, the phenomenon was pronounced only in the three conventional leads possessing a cranio-caudal spatial com-

FIG. 3.—The same patient as in Fig. 2. *Upper strip:* The “P-like” deflections are marked by x, the expiratory chest movements (as observed by inspection) are marked by horizontal bars. *Middle strip:* In the oesophageal lead (38 cm. from the nares) the phases of respiration are represented by the broad waves of the baseline. The respiratory electromyogram appears at the crest of each wave. The initial deflection is inverted. *Bottom strip:* The simultaneous record of lead II containing respiratory electromyogram deflections and of a faulty section of the oesophageal lead is shown to demonstrate the characteristic features of the respiratory electromyogram by comparison with AC interference.

TABLE

PRINCIPAL DIAGNOSES AND AGE-GROUPS OF 99 PATIENTS WHO EXHIBITED RESPIRATORY ELECTROMYOGRAM*

Principal diagnoses	Age-groups							All ages
	1 dy.—1 mth.	2 mth.—1 yr.	1½–16 yr.	31–48 yr.	51–59 yr.	60–69 yr.	70–87 yr.	
Congenital heart disease	5 (5)	7 (4)		1 (1)				13 (10)
Active carditis	1 (1)	1	2 (1)	1				5 (2)
Inactive rheumatic heart disease				3 (2)				4 (2)
Arteriosclerotic heart disease					1	4 (1)	4 (3)	10 (4)
Recent myocardial infarction					3 (3)	8 (7)		11 (10)
Hypertensive cardiovascular disease					1 (1)	3 (2)	3 (2)	7 (5)
Acute and subacute airway obstruction	2 (2)		1					3 (2)
Acute pneumonia, pneumothorax, atelectasis	2 (2)	6 (4)	2			2 (2)		12 (8)
Chronic bronchitis, obstructive lung disease			1 (1)	1	2 (1)	3 (2)	3 (3)	10 (7)
Primary chronic lung disease					1 (1)	2 (2)		3 (3)
Disseminated carcinomatosis with pleural or lung involvement				1 (1)	1 (1)			2 (2)
Pulmonary embolism				1 (1)		1 (1)		2 (2)
Attack of bronchial asthma				3	3			6
Infectious disease, abdominal emergency		2	2 (1)			1 (1)		5 (2)
Cerebrovascular accident					1 (1)		2 (2)	3 (3)
Metabolic coma					2 (1)		1 (1)	3 (2)
All diagnoses	10 (10)	16 (8)	8 (3)	11 (5)	17 (9)	24 (18)	13 (11)	99 (64)

* The proportion of fatalities is given in parentheses.

FIG. 4. A 3-month-old girl with Down's syndrome and severe dyspnoea. Unusually high initial deflection of the respiratory electromyogram. The infant died 2½ months later on January 4, 1966, and at necropsy an interatrial and an interventricular septal defect were found.

ponent, i.e. in the leads II, III, and AVF. This predilection cannot be easily understood when the origin of the deflections is sought in the heart, but it is plausible if we assume that the deflections are produced by the electrical activity of extracardiac muscle having a similar, longitudinal orientation. Possibly, the crura of the diaphragm or accessory respiratory muscles, e.g. the scalenes, are involved.

It is hazardous to draw conclusions from the only case in which we deemed it feasible to use an oesophageal lead on one of our dyspnoeic patients; however, it is worth mentioning that the respiratory electromyogram deflections showed the usual low amplitude when the electrode was kept at a level which produced distinctly augmented true atrial waves in the oesophageal cardiogram.

(c) Under certain conditions isolated inspiratory movements can produce minute oscillations in the cardiogram (Katz and Pick, 1956; Söderström, 1950; Higgins *et al.*, 1966). We have elicited such oscillations in a normal person by having him sniff forcibly.

(d) The present report, which is based on clinical experience, has shown that heterogeneous morbid states can produce the oscillations we are dealing

with only in the presence of severe respiratory distress. This observation seems to us to speak decisively for the respiratory origin of the phenomenon registered by the electrocardiograph.

Many unsolved questions await experimental and clinical investigation; for example, the physicochemical or neurological conditions which favour the inscription of the respiratory electromyogram. Does the phenomenon imply a worse prognosis than does dyspnoea *per se*? Or is it merely the electrocardiographic expression of respiratory distress?

The significance of the two elements which make up the respiratory electromyogram complex has to be clarified. We can only speculate that the initial P-like wave (often absent) and the minute oscillations which complete the complex are due to the action of different groups of muscle fibres, each of which produces its own electromyogram when excitation exceeds a certain level.

The possibility of detecting severe respiratory distress by the inspection of a routine electrocardiogram came to us as a surprise. That the phenomenon of the respiratory electromyogram has often been overlooked is indicated by numerous papers

FIG. 5.—A dyspnoeic 77-year-old man with multiple abscesses of the right lung and arteriosclerotic heart disease. Electrocardiogram taken one year before death. During one of the frequent attacks of transient atrial flutter with 2:1 AV conduction, the cardiogram shown in the four upper strips was recorded. The minute respiratory electromyogram oscillations—not preceded by a “P-like” deflection—appear synchronously with inspiration (markings above each strip) in leads II, III, and AVF. The phases of respiration are also indicated by deviations of the baseline. The bottom strip reproduces lead II recorded after the spontaneous restitution of sinus rhythm. The inscription of respiratory electromyogram oscillations persists in spite of the change in the heart rhythm.

specifically devoted to the electrocardiogram in respiratory diseases which fail to make any mention of it. Our interest in cardiac arrhythmias has induced us to study longer strips than those usually seen. It may be that repetitive minor disturbances of tracings are lost in the shorter strips commonly

employed. In addition, a psychological factor is operative in masking these small deviations from the normal. On scrutinizing an electrocardiogram one tends to look for changes in the configuration of atrial and ventricular complexes or for cardiac arrhythmias. As Scheerer (1963) pointed out, a

FIG. 6.—A 62-year-old man with diffuse pulmonary fibrosis and right heart failure. Previous electrocardiograms revealed the persistence of atrial parasystole. The reproduced section of lead II shows the sequence of atrial premature beats which follow every sinus beat. Only two of the atrial impulses are conducted to the ventricles. Respiratory electromyogram oscillations appear unrelated to the variations of the cardiac rhythm but in synchronization with the phases of respiration. Visible inspiration marked by horizontal bars. The patient died at home shortly after his discharge from hospital.

FIG. 7.—A 64-year-old man with a fresh posterior wall infarction, who died on the next day. The periodic appearance of the respiratory electromyogram deflections was not influenced by the transition from atrial fibrillation (lead II) to a regular supraventricular tachycardia (lead III). The minute respiratory electromyogram oscillations are easily differentiated from those due to AC interference.

“re-centering of one’s thoughts” is needed if a familiar object is to be viewed in an unconventional way.

SUMMARY

In 99 patients the electrocardiogram presented findings interpreted as electromyograms of respiratory muscles. The characteristic features of the respiratory electromyograms and their differentiation from other conditions are described.

In all these instances the patients suffered from severe dyspnoea and were seriously ill; 64 of them died while they were in hospital or shortly afterwards. The prognostic significance of the respiratory electromyogram is stressed.

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