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THE ELECTROMYOGRAM IN MYOPATHY: ANALYSIS WITH THE AUDIO-FREQUENCY SPECTROMETER

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Despite the fact that in most established cases of muscular dystrophy the clinical diagnosis is self-evident, occasional cases arise in which it is difficult to decide whether muscular wasting is of neuropathic or myopathic origin. Careful work by Kugelberg (1949) and others has shown that electromyography may be of considerable value in making this fundamental distinction, but in many centres the techniques for diagnosis are not yet firmly established. In this paper the electromyographic findings in 100 cases of myopathy are reviewed, and a method of frequency analysis is described which appears to enhance the value of the electromyogram in diagnosis. The results obtained by applying this analytical technique in the examination of 26 normal subjects and 48 patients with other neurological disorders are compared with those noted in the cases of myopathy. Before discussing the methods and results of the investigation, however, it is essential to discuss briefly the physiological principles involved and the findings of other authors.

The unit of muscle structure is the muscle fibre; under normal conditions muscle fibres never contract singly, but single fibre or fibrillation potentials can be recorded from resting muscle after denervation in the form of monophasic or diphasic spikes (Fig. 1) of about 1 millisecond duration (Weddell, Feinstein, and Pattle, 1944). Normal volitional activity of voluntary muscle is made up by the asynchronous contraction of individual motor units; each unit consists of the bundles of muscle fibres supplied by one anterior horn cell and its motor neuron. Electrically, the activity of the fibres of the unit summates smoothly to give a monophasic, diphasic, or triphasic wave, the motor unit action potential (Fig. 2), which varies between 4 and 10 milliseconds in duration (Petersén and Kugelberg, 1949). Hence it will be seen that in sustained contraction of voluntary muscle the dominant frequency of the electrical discharge, depending on the duration of the individual waves from which the complex wave form of the interference pattern is synthesized, will be of the order of 100 to 250 cycles per second. In disease of the anterior horn cell and the proximal part of the lower motor neuron it is clear that whole motor units, supplied by the diseased neuron, will perish, and for this reason the interference pattern will be reduced; eventually after the death of many neurons a needle electrode may record the activity from isolated surviving units, the "single discharge" of Buchthal and Clemmesen (1941). Under these circumstances, since the remaining motor units are of normal duration, the dominant frequency of the wave form will be unchanged.

In primary disease of the muscle, on the other hand (e.g. muscular dystrophy), no such anatomical pattern of degeneration obtains and individual muscle fibres die sporadically. No longer, therefore, is it possible for the activity of the fibres of a motor unit to summate smoothly, as some components of the unit will be missing, and for this reason many polyphasic potentials are seen (Fig. 3). If degeneration has proceeded further it may be that one or two fibres are all that remain of a motor unit and fibrillary potentials may be obtained on volition. Hence it will be expected that the dominant frequency of the electrical discharge from contracting dystrophic muscle will approach more nearly to 1,000 cycles per second. Kugelberg (1949) examined 16 cases of muscular dystrophy and carried out careful measurements of the motor unit potentials recorded. These findings were compared with those in 142 cases of neuropathy and it was confirmed that in the cases of myopathy a greatly increased proportion of polyphasic potentials and attenuated or short duration potentials was produced on contraction of the biceps brachii.

It should be remarked at this juncture that a number of polyphasic potentials are to be found on recording from normal muscle (Denslow and Hassett, 1943; Weddell and others, 1944); the proportion is about 2 to 4% in the biceps

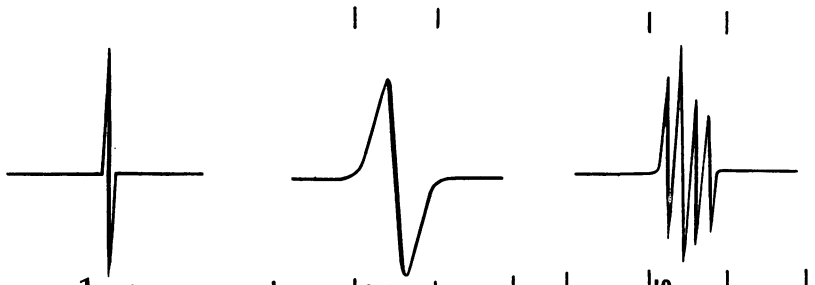

FIG. 1 FIG. 2 FIG. 3

FIG. 1.—Diagrammatic representation of a muscle fibre potential (amplitude about 100 microvolts).

FIG. 2.—Diagrammatic representation of a biphasic motor unit potential (amplitude about 1–2 millivolts).

FIG. 3.—Diagrammatic representation of a polyphasic, partially disintegrated, motor unit potential as seen in myopathy (amplitude about 500 microvolts).

muscle and considerably higher in the facial musculature (Petersén and Kugelberg, 1949). Similar disintegrated motor unit potentials also occur in large numbers during regeneration after a peripheral nerve injury, owing to the irregular reinnervation of fibre groups; they are also occasionally seen in cases of distal neuropathy where the degenerative process affects the nerve fibres distal to the point of branching of the motor neuron, when the scattered muscle fibres of the motor unit may degenerate at different rates (Richardson, 1951a, 1952). Fortunately the latter eventuality is uncommon, occurring only in occasional cases of polyneuritis, and the proportion of polyphasic potentials is not usually as great as that noted in cases of myopathy.

Other diagnostic features of the electromyogram in muscular dystrophy have been discussed by Kugelberg (1949) who pointed out that spontaneous fibrillation is absent in the myopathies but is often present in neuropathy; furthermore a sustained interference pattern is often readily obtainable from grossly wasted muscle in myopathy, whereas in the neuropathies the pattern, and in particular, the number of spikes, is usually reduced in proportion to the diminution of muscular power.

From the above information there has emerged a characteristic electromyogram of myopathy. The muscle is usually silent at rest, but on volition, even in extremely weak and wasted muscles, a highly complex polyphasic interference pattern will be produced, and the noise in the loudspeaker is high-pitched, like hail on a tin roof. In neuropathy, on the other hand, there is often spontaneous fibrillation with the muscle at rest, and on volition the interference pattern is interrupted or reduced. The loudspeaker gives an intermittent, low-pitched rumble, save in occasional cases where the neuropathic degeneration is predominantly distal, when a certain number of polyphasic potentials, with their high-pitched, crackling note, may be added.

However, although the characteristic findings described above are almost invariably noted in established cases where the clinical diagnosis has been made with ease, it is in the cases which give rise to diagnostic difficulty clinically that the electromyogram may also give equivocal results. The presence of a small proportion of polyphasic potentials may obscure the underlying potentials of normal duration; on the other hand the observer may not consider that such high frequency activity is present in sufficient quantity for a firm diagnosis. Visual analysis of the ephemeral trace on a cathode ray screen is notoriously unreliable; admittedly it is possible to submit the photographed record to detailed visual or mathematical analysis, but this procedure is time-consuming, and certainly any complex wave-form may contain components which are invisible to the eye (Dawson and Walter, 1944). Furthermore, sampling and measurement of individual motor units is also laborious and it is impossible to be certain that the recorded data are representative of the whole muscle.

For these reasons it was decided to seek a convenient method of instantaneous frequency analysis of the electromyogram. Recently Richardson (1951b) has described a simple technique; his analyser is based on electronic filters and integrating voltage meters which filter off the frequency components above 400 cycles per second and measure them. He has suggested that an increase in the measurement of these high frequencies compared with those below 400 cycles indicates a myopathic lesion, but his method has not yet been applied to a large series of cases. In 1946 Agate and Druett reported the results of an investigation in which an audio-frequency spectrometer was utilized to study vibrations transmitted to the hands; since the frequency spectrum covered by this instrument

seemed satisfactory it was decided to employ it as an analyser of the electromyogram.

Material

One hundred cases of myopathy have been examined; a clinical study of these cases is to be reported in detail elsewhere. The cases are listed according to the clinical type of the disease in Table I; the diagnoses of other cases examined by this method, for comparison, are also given.

TABLE I
ANALYSIS OF CASES EXAMINED

	Diagnosis	No. of Cases
Cases of Myopathy	Pseudohypertrophic muscular dystrophy	43
	Facio-scapulo-humeral muscular dystrophy (Landouzy-Déjerine)	12
	Late juvenile muscular dystrophy (Erb's scapulo-humeral type)	19
	Dystrophia myotonica	15
	Muscular dystrophy of late onset (Nevin)	3
	Distal myopathy of Gowers	1
	Ocular myopathy	1
	Atypical myopathy	6
	Total	100
Other Cases	Normal controls	26
	Motor neuron disease	13
	Polyneuritis	4
	Neuralgic amyotrophy	2
	Dermatomyositis	2
	Myotonia congenita (with no evidence of muscular wasting)	6
	Amyotonia congenita (Oppenheim)	1
	Peripheral nerve injury	8
	Facial paralysis	9
	Cervical spondylosis	3
	Total	74

Methods

All records were taken using standard concentric needle electrodes and the "stanco" double channel electromyograph. For the investigation only one channel of the apparatus was required and the output of this channel was fed into the audio-frequency spectrometer. A photograph of the apparatus is given in Fig. 4.

For technical details of the spectrometer the reader is referred to the paper by Agate and Druett (1946). Briefly, it consists of 27 resonant circuits tuned to frequencies distributed logarithmically throughout the 40–16,000 c.p.s. range, each having an associated storage condenser. These are scanned sequentially every 1/24 of a second by a rotary switch and their accumulated voltages are fed first into a modulator and thence on to the Y-plates of a cathode ray oscilloscope. Incremental X-deflections provided by the switch itself combine to produce on the screen a frequency/volt × second histogram. At rest the screen shows a row of dots each corresponding to a particular frequency (Fig. 5); when any wave form is fed into the instrument vertical lines appear on the dot of the responding frequencies, the amplitude of each line being proportional to the amount of the frequency concerned. Care must be taken in adjustment of the gain control to prevent overloading,

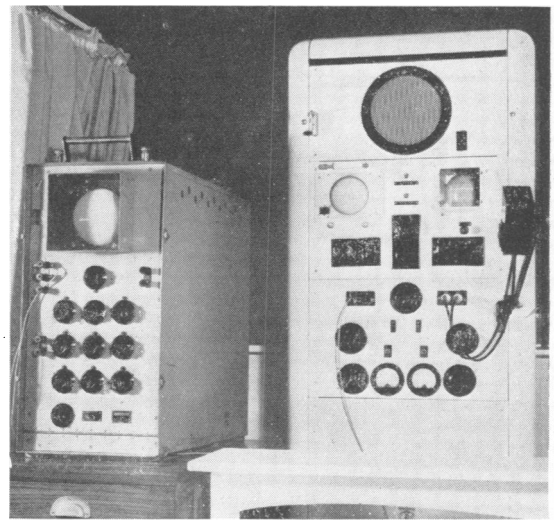

FIG. 4.—The double channel electromyograph and the audio-frequency spectrometer (on the left).

since when this occurs excessive responses may be produced at harmonics of the responding frequencies, and this may encourage erroneous interpretation. With experience, this error is easily avoided.

Except in young children, where needling of muscle was ill-tolerated, at least three separate muscles were examined in every case of myopathy, each with a single insertion. Two or more muscles were examined similarly in the controls and other patients. Extensive probing was then carried out and the electromyogram, with a simultaneous analysis, was obtained first at rest and then on volition, with the needle point in at least five separate positions within the muscle. Direct visual and auditory analysis was relied upon for interpretation of the electromyogram, but the spectrometer histogram was invariably photographed, either with a 16 mm. "ciné kodak" camera supplied with the apparatus, or occasionally by making repeated single exposures on 35 mm. film with a "leica". For statistical reasons, extensive sampling of individual muscles, using several insertions, with the needle point at standard depths within the muscle, was envisaged, but the practical difficulties were so great and so many variable factors were involved that this plan was discarded. Furthermore it soon became clear from the unequivocal results obtained that the added discomfort occasioned to patients by repeated and extensive explorations was both unnecessary and unjustifiable. As it was also clear that the analysis was unaffected (except in the amplitude of its components) by increasing activation, no account was taken of the power of contraction of individual muscles, but as a rule the record was taken during maximum voluntary effort against resistance.

Results

Normal Controls.—Before any patients with myopathy or other neurological disorders were

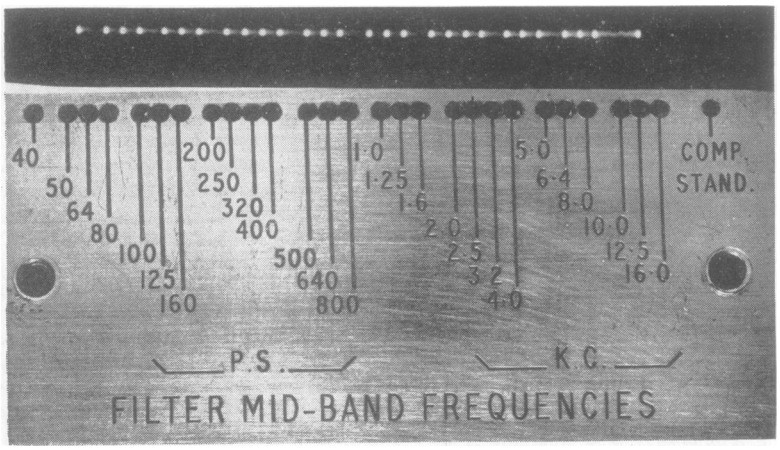

FIG. 5.—The appearance of the screen of the spectrometer with no input applied. The row of dots described in the text are seen, and a key is superimposed indicating the frequencies corresponding to each dot.

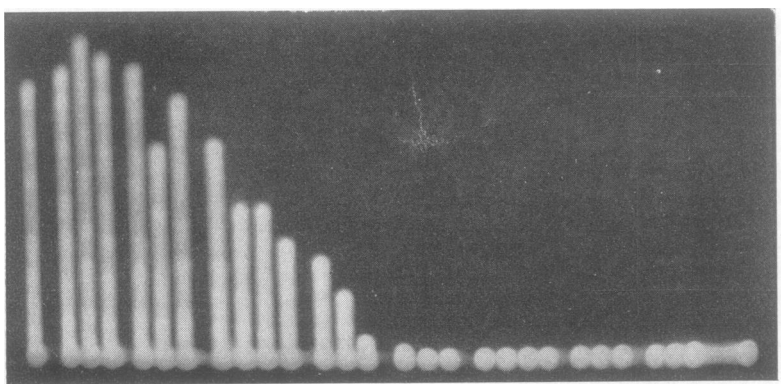

FIG. 6.—The histogram produced on contraction of proximal or long limb muscles in a normal subject: the normal response.

examined a total of 36 examinations were made on 26 control subjects, 16 males and 10 females. Although most of the subjects were junior medical staff or students and hence in the third or fourth decades the results obtained in the few children and elderly people examined did not suggest that the frequency analysis varied significantly with age. Three separate examinations in different subjects were made of each of the following muscles: orbicularis oris, masseter, deltoid, pectoralis major, biceps brachii, brachioradialis, flexor pollicis brevis, adductor pollicis, gluteus maximus, quadriceps femoris, gastrocnemius, and tibialis anterior. In all the large limb muscles the spectrometer histogram obtained when the muscle contracted was quite uniform, showing a peak frequency response at 100–200 cycles per second, and tailing off to zero at about 800 cycles. Fig. 6 is an example of the pattern obtained from the deltoid muscle of a normal subject; this standard response will hereafter be referred to as the normal pattern. The pattern did not vary when the needle was moved into many different parts of the muscle, nor did it depend on the degree of activation.

A significantly different histogram was produced on examination of the masseter and orbicularis oris; the dominant frequency in these situations was at 200–250 c.p.s. and the spectrum was broadened by the accession of higher frequencies, with some response even at 1,500 c.p.s. Fig. 7 is an example of this type of histogram, which will be referred to as the broad spectrum type of response. A spectrum of this type was also obtained frequently from the flexor pollicis brevis and has since been observed in recordings from other small hand muscles in normal subjects. These observations can be correlated with the fact already mentioned that a high proportion of polyphasic potentials can be obtained from the normal facial musculature; it appears that the same findings apply to the small muscles of the hand.

Myopathy.—It will be convenient to consider first the results of frequency analysis, and then other electromyographic findings in these cases.

Frequency Analysis.—On examination of the first case it was immediately evident that on recording from muscles severely affected by the dystrophic process a spectrometer histogram could be obtained which differed significantly from any of the findings in normal subjects. In this pattern there was a relative absence of the lower frequencies and there was a complete shift to the right of the dominant frequency. An example is given in Fig. 8, which shows the histogram obtained from the contracting pectoralis major of a patient with facio-scapulo-humeral muscular dystrophy. It will be seen that the dominant frequency response is at 640 c.p.s., and the response at 100–250 c.p.s. is compara-

tively scanty. This pattern will be referred to as the shift type of histogram. It has been considered that a significant shift occurred when the dominant frequency exceeded 400 c.p.s. Such a pattern was never seen in any situation, even after extensive probing, in the normal subjects examined. Detailed results are given in Table II.

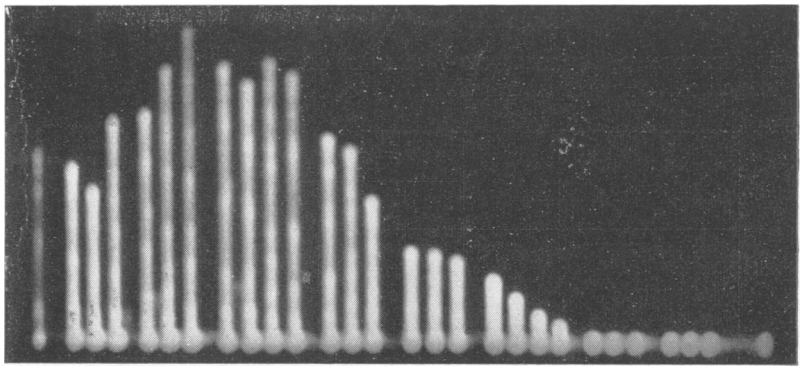

FIG. 7.—The histogram produced on contraction of facial muscles or small hand muscles in a normal subject: the broad spectrum type of response. A similar pattern is obtained on examination of relatively unaffected muscles in patients with myopathy.

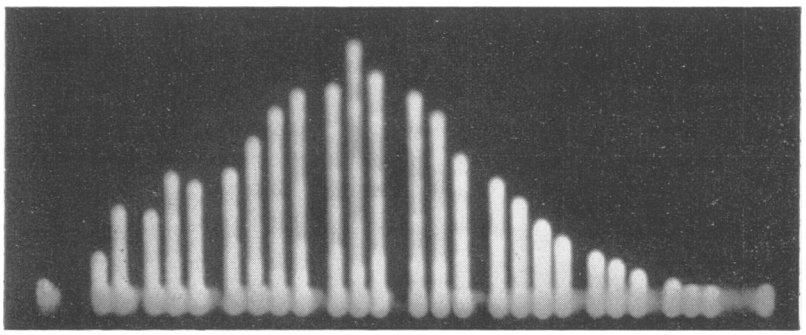

FIG. 8.—The histogram produced on contraction of the pectoralis major in a patient with facio-scapulo-humeral muscular dystrophy, showing a shift to the right of the dominant frequency: the shift type of response.

In 98 of the 100 cases examined it was possible to obtain a shift type of analysis from at least one of the muscles examined. In some cases, particularly those in which the disease process was advanced, such a pattern was seen on volition whenever the needle was randomly inserted into the muscle. On other occasions some probing was necessary before a shift occurred, the pattern from the remainder of the muscle being occasionally normal (in early cases), but more often giving a broad spectrum response. It was noted that in such cases a shift was most commonly obtained on recording from the more superficial portions of the muscle, suggesting that degeneration was more advanced in this situation. The two patients in whom no shift was obtained were young children in whom the examination was of necessity brief and incomplete; in both cases the analysis was abnormal, a broad spectrum response being obtained from long limb muscles, but it is probable that a shift would have occurred with more extensive probing.

Consideration of the results listed in Table II will show that as would be expected a shift was most readily obtained from the muscles most affected by the disease process. Thus in dystrophia myotonica, where the myopathic process is predominantly distal in distribution, the characteristic findings were obtained from forearm muscles and those below the knee. In the other forms of muscular dystrophy, where proximal muscles are chiefly involved, the most definite results were obtained from examination of the pectoralis major and biceps brachii in the upper limbs and quadriceps and tibialis anterior in the lower. A parallel clinical survey has shown that the spinati, deltoid, and gastrocnemius may remain relatively powerful until a late stage of the disease in these cases, and it will be seen that the pattern of analysis was generally less abnormal when these muscles were examined. Hence it is suggested that for the examination to be of most value the pectoralis major, biceps brachii, quadriceps, and tibialis anterior should be examined in cases of muscular dystrophy of the proximal type, while in dystrophia myotonica and distal myopathy attention should be turned to the long flexors and extensors of the fingers and tibialis anterior.

Spontaneous Activity.—Kugelberg (1949) has stressed that the absence of fibrillation is in favour of the diagnosis of myopathy; spontaneous fibrillary potentials were not observed in any case of the present series. On several occasions repetitive spike potentials, indistinguishable from fibrillation, were seen with the muscle apparently at rest, but on each occasion these discharges disappeared when the patient was urged to relax, and it is clear that these

TABLE II

THE RESULTS OF FREQUENCY ANALYSIS OF THE ELECTROMYOGRAM IN PATIENTS WITH MYOPATHY

	Muscle Examined	No. of Insertions	Type of Spectrum Obtained		
			Shift	Broad Spectrum	Normal
Pseudohypertrophic Muscular Dystrophy (43 Cases)	Deltoid	6	2	3	1
	Biceps brachii	17	12	5	—
	Pectoralis major	16	12	4	—
	Supraspinatus	5	3	1	1
	Triceps	5	3	1	1
	Brachioradialis	3	1	2	—
	Quadriceps femoris	19	13	4	2
	Tibialis anterior	17	11	5	1
	Gastrocnemius	18	5	8	5
Facio-scapulo-humeral Muscular Dystrophy (12 Cases)	Pectoralis major	7	6	1	—
	Supraspinatus	5	1	3	1
	Biceps brachii	4	3	1	—
	Brachioradialis	3	2	1	—
	Orbicularis oculi	2	—	2	—
	Orbicularis oris	2	—	2	—
	Quadriceps femoris	6	4	2	—
	Gluteus maximus	4	2	2	—
Late Juvenile Type of Muscular Dystrophy (9 Cases)	Pectoralis major	12	10	2	—
	Deltoid	6	3	3	—
	Biceps brachii	14	11	3	—
	Supraspinatus	4	1	3	—
	Quadriceps femoris	7	4	3	—
	Gluteus maximus	2	1	1	—
	Tibialis anterior	7	4	3	—
	Gastrocnemius	3	—	1	2
Dystrophia Myotonica (15 Cases)	Flexor digitorum	10	8	2	—
	Thenar eminence	7	4	—	3
	Extensor digitorum	7	6	—	1
	Orbicularis oris	3	1	2	—
	Quadriceps femoris	7	2	3	2
	Tibialis anterior	12	11	1	—
	Gastrocnemius	8	3	5	—
Nevin Type of Muscular Dystrophy (3 Cases)	Pectoralis major	2	1	1	—
	Supraspinatus	2	—	1	1
	Biceps brachii	2	2	—	—
	Gluteus maximus	1	1	—	—
	Quadriceps femoris	2	1	1	—
	Tibialis anterior	1	1	—	—
Ocular Myopathy	Orbicularis oculi	1	1	—	—
	Biceps brachii	1	—	1	—
	Tibialis anterior	1	—	1	—
Distal Myopathy (Gowers)	Extensor digitorum	1	—	1	—
	Thenar eminence	1	1	—	—
	Adductor pollicis	1	1	—	—
	Tibialis anterior	1	1	—	—
Atypical Myopathy (6 Cases)	Pectoralis major	2	1	1	—
	Deltoid	2	2	—	—
	Biceps brachii	3	2	1	—
	Gluteus maximus	2	—	1	1
	Quadriceps femoris	4	3	1	—
	Tibialis anterior	4	2	2	—
	Gastrocnemius	3	1	2	—

were myopathic short duration potentials which were occurring because of incomplete relaxation of the muscle. It is important to recognize this pitfall which may give rise to considerable diagnostic difficulty. Single motor unit or fasciculation potentials which commonly occur spontaneously in motor neuron disease were not seen in any case of myopathy nor did any case show the characteristic grouped potentials of nerve irritation.

Spontaneous chains of oscillations of high frequency, attributable to muscular hyperexcitability, give rise to one of the most dramatic phenomena encountered in clinical electromyography. The characteristic "dive-bomber" or "quasi-musical" sound produced in the loudspeaker by this type of discharge is quite unmistakable (Buchthal and Clemmesen, 1941). This phenomenon is almost invariable in the myotonias on stimulation of the resting muscle with the needle point, but it has also been noted infrequently in progressive muscular atrophy, fatigued normal muscle, cramp, and anterior poliomyelitis (Richardson, 1951a, 1952). In the present series spontaneous activity of this type was recorded in all 15 cases of dystrophia myotonica and in six cases of myotonia congenita. It was also obtained, however, in 16 cases of muscular dystrophy without myotonia (11 pseudo-hypertrophic, two facio-scapulo-humeral, three late juvenile), in two out of 13 cases of progressive muscular atrophy, and in one case of dermatomyositis. The discharge was invariably less dramatic and less easily obtained in the cases of simple dystrophy than in those with myotonia, and as a rule the sound decreased in pitch much more slowly. It is of interest that a similar phenomenon, giving a "rasping" note slowly decreasing in pitch, was obtained on recording from shoulder girdle muscles during voluntary contraction in nine cases of muscular dystrophy. It is convenient at this point to mention the pattern of analysis produced by this phenomenon. As Richardson (1952) has mentioned, the individual components of the chain of oscillations sometimes have the dimensions of single fibre potentials, some resemble motor units, and others are polyphasic and bizarre. As would be expected, therefore, the spectrometer showed a broad spectrum type of response during recording of this activity; it was also noted that as the sound in the loudspeaker waned, those vertical lines of the spectrometer histogram corresponding to the higher frequencies fell out in turn, rather like a row of chorus girls falling one by one on to the stage. This "chorus girls" effect is amusing and, in the author's experience, it is quite diagnostic of the type of discharge under consideration, but it

cannot be considered important, as the electromyographic pattern is itself characteristic. It can be concluded that whereas dramatic, repetitive, and easily obtainable chains of oscillations of high frequency with the concomitant " dive-bomber " note remain characteristic of myotonia, similar but less impressive discharges may be obtained in patients with muscular dystrophy both at rest and on volition and in a number of other conditions ; the exact significance of these discharges remains obscure.

Volitional Activity.—Apart from the characteristic pattern of analysis already described, few observations of importance on the electromyographic pattern during voluntary contraction have been made in patients of this series. It has been possible to confirm Kugelberg's (1949) observations that even in grossly wasted muscles, with scarcely a flicker of voluntary contraction visible clinically, a sustained though highly polyphasic interference pattern may be obtained. It has also been confirmed that the amplitude of the action potentials of dystrophic muscle is greatly reduced in comparison with normal motor unit potentials, as would be expected in view of unit disintegration. These findings suggest that the muscular power represented by the dystrophic short duration potential is greatly reduced when compared with that of a normal motor unit potential.

It has also been noted that in recording from a muscle showing pseudohypertrophy, say the gastrocnemius, many parts of the muscle bulk may be electrically silent even during a powerful contraction ; presumably this observation can be correlated with the pathological finding of extensive fatty infiltration in such muscles.

Other Conditions.—The diagnoses of the patients examined in this section of the investigation have been noted in Table I. In this section attention will be confined to the pattern of analysis obtained in these cases, since this study is not concerned with the other electromyographic findings in these many disorders. In Table III the type of analysis obtained during voluntary contraction of stated muscles in these patients is given.

It will be seen from the results outlined in Table III that in general the pattern of analysis seen in patients with neuropathy has been entirely different from that obtained in the myopathies. A shift of the spectrum to the right occurred only in the cases of dermatomyositis and in patients with regenerating peripheral nerve injuries or recovering facial palsy. From the principles already outlined these findings would be expected, since in dermatomyositis the disease process occurs within the muscle itself, as in myopathy, and as already mentioned, profuse polyphasic " recovery " potentials occur during recovery from a peripheral nerve injury. In all the patients with neuropathy, save one case of polyneuritis, the pattern of analysis for the particular muscles examined was normal, even after extensive exploration ; in one patient with polyneuritis (in

TABLE III

FREQUENCY ANALYSIS IN PATIENTS WITH OTHER NEUROLOGICAL DISORDERS

	Muscle Examined	No. of Insertions	Type of Analysis Obtained		
			Shift	Broad Spectrum	Normal
Motor Neuron Disease (13 Cases)	Pectoralis major	3	—	—	3
	Deltoid	6	—	1	5
	Biceps	2	—	—	2
	Brachioradialis	2	—	—	2
	Adductor pollicis	3	—	1	2
	Thenar eminence	3	—	2	1
	Quadriceps femoris	7	—	—	7
	Tibialis anterior	4	—	—	4
	Gastrocnemius	2	—	—	2
Polyneuritis (4 Cases)	Extensor digitorum	3	—	1	2
	Thenar eminence	3	—	2	1
	4th dorsal interosseus	2	—	—	2
	Tibialis anterior	5	—	—	5
Neuralgic Amyotrophy (2 Cases)	Supraspinatus	2	—	—	2
	Deltoid	2	—	—	2
	Triceps	1	—	—	1
Cervical Spondylosis (3 Cases)	Deltoid	2	—	—	2
	Thenar eminence	3	—	2	1
	4th dorsal interosseus	3	—	2	1
Myotonia Congenita (6 Cases)	Flexor digitorum	3	—	—	3
	Extensor digitorum	3	—	—	3
	Tibialis anterior	5	—	—	5
Amyotonia Congenita (1 Case)	Biceps brachii	2	—	—	2
Dermato-Myositis (2 Cases)	Quadriceps femoris	2	2	—	—
	Deltoid	2	1	1	—
Peripheral Nerve Injury (8 cases)	Serratus anterior	2	1	—	1
	Supraspinatus	2	—	1	1
	Thenar eminence	2	1	1	—
	4th dorsal interosseus	6	2	3	1
	Adductor pollicis	4	1	3	—
Facial Palsy (9 Cases)	Orbicularis oculi	9	1	7	1
	Orbicularis oris	9	2	7	—

association with porphyria) an excessive amount of high frequency discharge was obtained from the forearm musculature, but the proportion was never sufficiently great in this case to produce a shift of the dominant frequency.

It is unlikely that clinical confusion will ever arise between cases of recovering peripheral nerve injury and myopathy; hence it can be suggested with confidence that this method provides a diagnostic tool for the unequivocal differentiation of myopathy and neuropathy. Both cases of dermatomyositis examined were referred for examination as cases of muscular dystrophy, and the correct diagnosis was reached only through the observation of an unusual pattern of muscular weakness combined with induration of subcutaneous tissue and minimal scleroderma-like changes in the skin of the hands and face. Clearly occasional cases of this condition will continue to cause confusion with muscular dystrophy; as would be expected from the physiological principles, electromyography is of no value in distinguishing these two conditions which must be separated by clinical and pathological methods.

Conclusions

The use of the audio-frequency spectrometer in the analysis of the electromyographic interference pattern has given results in patients with myopathy which are significantly different from those obtained in control subjects and in patients with other neurological disorders, with the exception of dermatomyositis and recovering nerve injury. It is suggested that this refinement of electromyographic technique is of considerable value in distinguishing between neuropathy and myopathy. The apparatus utilized in the investigation is probably too complex and expensive for routine use, but the results suggest that a simple type of analyser, designed on similar lines, is likely to be a valuable adjunct in diagnostic electromyography.

Summary

A method of frequency analysis of the electromyogram, utilizing an audio-frequency spectrometer, has been applied to the examination of 100 cases of myopathy, 26 normal subjects and 48 patients with other neurological disorders. The method was developed since electromyography has not given uniformly successful results in the diagnosis of myopathy, even though disintegration of the motor unit potential, with numerous polyphasic and short duration potentials, has been recognized in such cases. Analysis of the interference pattern of muscular contraction in normal subjects revealed a consistently normal pattern with the dominant response at 100–250 c.p.s., tailing off to zero at 800 c.p.s., save in facial muscles and small muscles of the hand, where a proportion of higher frequencies up to 1,250 c.p.s. was added.

In 98 of the 100 cases of myopathy the analysis obtained on contraction of at least one of the muscles examined showed a shift to the right of the dominant frequency compared with the pattern observed in normal subjects. These findings were most readily obtained from the superficial part of the muscle and in muscles severely affected by the disease process (pectoralis major, biceps brachii, quadriceps femoris, and tibialis anterior in the "proximal" types of muscular dystrophy, the long flexors and extensors of the fingers and tibialis anterior in dystrophia myotonica and distal myopathy). A similar shift of the dominant frequency occurred in patients with dermatomyositis and recovering peripheral nerve injury, but on extensive exploration in cases of neuropathy, including 13 patients with motor neuron disease, a normal analysis was practically invariable and no frequency shift was observed.

Spontaneous fibrillation was not observed in any case of myopathy; chains of oscillations of high frequency were recorded on probing in resting muscle in 15 out of 15 cases of dystrophia myotonica, six out of six cases of myotonia congenita, and in 16 out of 85 cases of muscular dystrophy with no clinical evidence of myotonia.

It is suggested that the addition of a method of frequency analysis as described enhances the value of electromyography in distinguishing between myopathic and neuropathic disorders.

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References

Agate, J. N., and Druett, H. A. (1946). *Brit. J. industr. Med.*, **3**, 159.
Buchthal, F., and Clemmesen, S. (1941). *Acta psychiat., Kbh.*, **16**, 389.
Dawson, G. D., and Walter, W. G. (1944). *Journal of Neurology, Neurosurgery and Psychiatry*, **7**, 119.
Denslow, J. S., and Hassett, C. C. (1943). *Amer. J. Physiol.*, **139**, 652.
Kugelberg, E. (1949). *Journal of Neurology, Neurosurgery and Psychiatry*, **12**, 129.
Petersén, I., and Kugelberg, E. (1949). *Ibid.*, **12**, 124.
Richardson, A. T. (1951a). *Arch. phys. med.*, **32**, 199.
——(1951b). *St Thom. Hosp. Rep., Ser.* **2**, **7**, 164.
——(1952). *Ann. phys. Med.*, **1**, 88.
Weddell, G., Feinstein, B., and Pattle, R. E. (1944). *Brain*, **67**, 178.