THE MEASUREMENT OF MUSCLE TONUS

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Muscle tonus influences many of the bodily functions, and attention has recently been directed to the importance of hypotonia as a cause of post-operative atelectasis and circulatory failure.¹ Accordingly, a method for the measurement of muscle tonus is greatly needed, and much work has been done with this object in view. The elastometers of Wertheim Salomonson, Noyons,² Mangold,³ and Gildemeister⁴ are ingenious pieces of scientific apparatus, but are open to so much criticism that they have never come into general use. Gildemeister's method of measuring tonus by means of a hammer and ballistic galvanometer has been used clinically by Springer,⁵ Hosiosky,⁶ and others,⁷ but the readings obtained in this way vary considerably with the amount of subcutaneous fat present in the part under observation. The use of such apparatus shows the resistance of the tissues to a deforming force, and cannot be claimed to give an accurate estimate of muscle tonus. The elaborate apparatus of Fenn and Garvey⁸ is of value for research rather than for clinical purposes. In fact the only practical method available at the bedside has been until recently the estimation of the degree of passive movement obtainable at the joints. By this means gross hypotonia could be appreciated, but could not be recorded graphically.

It is scarcely necessary to emphasize the fact that there is always a certain tonic longitudinal pull exerted by the bundles of fibres in a muscle, even when at rest. The internal pressure is therefore dependent upon the tonicity of the fibres, and varies throughout the body according to the state of contraction or relaxation present. However, by ensuring that the muscle examined is relaxed these variations can be avoided, and an estimate obtained of the degree of tonus present in that particular muscle. This enables the variations in tonus produced by different general conditions to be studied.

The method recently described by Yandell Henderson and his co-workers⁹ is based upon this fact, and depends on measuring the pressure required to induce a minute amount of saline to run through a hollow needle introduced into the body of a muscle. The principle of the method is that the fluid will exert a side-thrust on the muscle fibres, tending to displace them, and that this displacing force will be resisted by the tonicity of the fibres. This represents an entirely new way of approaching the problem, and confirmation of its utility becomes necessary. An investigation based on these conclusions has already been carried out, and consistent results seem to have been obtained.¹⁰ However, little attention has been paid to the variations produced by disease and their bearing on prognosis and treatment. The purpose of this paper is to determine the suitability of the apparatus for use as a clinical instrument and to discuss some of the problems which have arisen during the investigation.

The Original Procedure

Apparatus.—A No. 4 serum needle is used for insertion into the muscle. To obviate the risk of the needle becoming blocked by a small portion of muscle tissue it is recommended that the end of the needle should be blocked with solder, and three holes made at the side, near the point, by means of a file. In our experience the danger of the needle, thus weakened, breaking during use is more apparent than real.

A piece of capillary glass tubing of 1 mm. bore and 5 cm. length is inserted into the butt-end of the needle, having been previously ground so as to give an accurate junction. The pressure is measured by a U-tube water manometer, graduated from 0 to 200 millimetres, which is connected to the glass tube by means of thick rubber tubing. By turning a fine thumbscrew a rubber bulb, attached at the bend of the U, is compressed, thus filling the manometer with water to any desired level.

Method.—The left biceps was chosen by the original workers as being the most convenient muscle for examination in this way. This choice has been adhered to in the present series, except where the presence of a skin affection or other local lesion has rendered the choice of the right biceps more advisable. The subject lies on his back. An area of skin over the left biceps is sterilized in the usual way and anaesthetized with novocain. The arm is flexed to about 135 degrees to ensure relaxation, and the needle to be used is filled with saline and thrust into the muscle. The glass tubing is filled to about two-thirds of its length with saline solution, and then inserted into the butt of the needle. This degree of filling is best obtained by using a hypodermic syringe with a needle sufficiently fine to be introduced within the bore of the glass tubing. The free end of the glass tubing is now connected to the manometer. One observer raises the pressure in the manometer by rotating the thumbscrew, while a second watches the fluid meniscus until it starts to move. When this occurs he signals to the first observer, who reads the pressure recorded by the manometer. It is this first movement of the meniscus, indicating that intramuscular pressure has been overcome, that is taken as representing the existing degree of tonus. The first reading is discarded and an average is taken of the next three.

The Modified Procedure

We have obtained good results by using the apparatus as described, but certain minor disadvantages have been apparent. Some difficulty was encountered in grinding the glass tubing to make an accurate junction with the needle. Moreover, capillary attraction proved troublesome when using tubing of such a fine bore as 1 mm. Accordingly we sub-

Diagram showing: A, Water manometer. B, Needle and capillary glass tubing as originally described. C, Author's modifications. (Not drawn to scale.)

stituted a glass tube of 2 mm. bore, furnished with metal adapters at the ends: no loss of efficiency resulting from this alteration has been noted.

Since the manner of filling the glass tubing also proved somewhat inconvenient, a reservoir was added to the apparatus. A metal T-piece, with a cock on the vertical limb, was inserted between the needle and the glass tubing, and the barrel of the 1 c.cm. syringe was attached to the vertical limb, so providing a convenient reservoir. By turning the cock the apparatus can be filled with saline to the desired level with the needle *in situ* and without disconnecting the manometer.

Results

The apparatus as described is inexpensive and easy to construct. Little dexterity is required for its use, and this is especially true if the suggested modifications are

adopted. The operation is almost painless where the skin has been adequately anaesthetized, and for this purpose a delay of at least five minutes is recommended between the infiltration of the skin with novocain and the insertion of the needle. Apart from this the time taken to obtain a reading is small, and twenty minutes should suffice for the examination of half a dozen patients. Consistent results are obtained in the one individual, but in this connexion we are not sure that differences of less than 5 mm. of water are significant.

Altogether the simplicity of the apparatus and the absence of technical difficulties make the method eminently suitable for use at the bedside. A number of readings have been carried out on some 200 individuals, mostly patients in general medical wards, and the occurrence of hypotonia has been noted. No attempt has been made in the present series to measure increased tonus occurring in cases with evidence of spasticity. Henderson, Oughterson, Greenberg, and Searle⁹ obtained readings of between 60 and 90 mm. in ten healthy young men, and these figures correspond closely with those which we have obtained in convalescent patients who could reasonably be regarded as being in good health.

Grouping of Cases

The present series is too small to permit of any classification of results on an aetiological basis. Indeed, it does not appear that this would be of any value, since hypotonia in a greater or less degree is a result of many diseases, and not a specific result of any one ailment. For the purposes of this investigation the clinical condition of the patient at the time of examination has been used as a basis for tabulating the results.

Working on this principle three groups have been established. Group 1 consists of persons who have come under observation on account of some symptom which has not appreciably impaired their vitality. Patients who are obviously ill but not in immediate danger of death constitute Group 2. Group 3 includes all cases where the illness is grave. Typical findings are shown in the following table.

TABLE I

Group 1	Group 2	Group 3
Fibrositis ... 60	Myxoedema... 23	Auricular fibrillation 60
Glycosuria ... 75	Arthritis ... 40	Nephritis ... 20
Peptic ulcer ... 80	Paget's disease ... 100	Empyema ... 15
Anxiety neurosis 70	Carcinoma of lung 60	Mitral disease ... 65
Hyperpiesis ... 90	Osteomalacia ... 45	Hemiplegia ... 30
Normal ... 90	Splenic anaemia ... 85	Haematemesis ... 25
Abdominal pain ... 75	Acute rheumatism... 50	Pulmonary tuberculosis 60
Syphilis ... 75	Syphilitic aortitis... 60	Diabetic gangrene ... 50

Readings in millimetres of water.

It will be noticed that, although marked illness usually depresses muscle tone, the degree of depression does not correspond to the clinical condition. This is contrary to the findings of previous observers.⁹ Moreover, in our experience, during the course of non-survival experiments on the cat, the readings obtained with this apparatus in no way correspond with the physical condition of the animal.

In hospital wards we have repeatedly observed that moribund patients may give higher readings than those whose condition does not give rise to immediate anxiety. Furthermore, low figures may be obtained where the only complaint is that of weakness and where objective findings are negative. Accordingly we do not regard the measurement of muscle tonus in this way to be of any value in prognosis.

This conclusion is not surprising, since it is not to be expected that any one clinical finding would prove to be of constant value for this purpose. On the other hand, in certain cases hypotonia as demonstrated by this method has been the only positive finding, and we have been able to show and measure disturbance of function in a number of so-called neurasthenics. This is regarded as an important result, since it provides a ready means of following the progress of the case and of estimating the response to treatment without the necessity of relying solely on the patient's statements as to improvement.

The number of patients diagnosed as suffering from neurasthenia has been greatly reduced since the recognition and better comprehension of the anxiety states. This reduction, however, still leaves many cases which cannot be classified under any other heading. The introduction of any device which enables positive findings to be obtained in such cases cannot but be valuable. It may be mentioned in passing that many of these individuals had very active tendon reflexes in spite of depressed muscle tonus.

Influence of Circulatory Depression

Henderson¹¹ has shown the effect of tonic muscular contraction in promoting a continuous flow of blood through the veins to the heart, and has emphasized the importance in the maintenance of the circulation of this factor, which he terms the "veno-pressor mechanism." Following on the work of Riml¹² it has been shown⁹ in the case of the cat that this pressure alone is sufficient to drive one-quarter of the blood volume into the right heart in a few seconds. Therefore it would be reasonable to expect that some degree of circulatory failure would be apparent in those cases which showed marked hypotonia.

Table II compares the findings in patients suffering from obvious cardiac disease with those obtained in certain cases where the heart was unaffected.

TABLE II

Patients with Heart Disease	Patients without Heart Disease
Auricular fibrillation ... 55	Asthenia ... 40
Coronary thrombosis ... 30	Pulmonary tuberculosis ... 50
Myocarditis ... 80	Secondary carcinoma ... 30
Heart block ... 90	Post-pneumonic asthenia ... 25

Readings in millimetres of water.

The difference in the clinical condition of those two groups was striking. In the one dyspnoea, oedema, and tachycardia were prominent features, while in the other there were no obvious signs of cardiac distress, and yet hypotonia was marked. At first sight it would appear that the importance of this "veno-pressor mechanism" has been exaggerated, but on examining the matter more closely a different conclusion was reached.

All these hypotonic individuals with no apparent heart lesion showed some distress on exertion. Palpitation, weakness, and dizziness were complained of, and the pulse rate returned to normal somewhat slowly. In other words, they resembled those cases variously described as neuro-circulatory asthenia, effort syndrome, or disordered action of the heart. Further research on this point is required, but it is suggested that a number of cases of neuro-circulatory asthenia are, in fact, suffering from depressed muscle tonus resulting in defective venous return. The primary cause of this hypotonia might be ascribed to the existence of some previous or concurrent infection.

Summary

The measurement of muscle tonus is discussed, and the utility of a previously described method is confirmed. Modifications of the original apparatus are suggested.

Findings obtained in a series of some two hundred patients are analysed and considered with regard to prognosis.

Observations are made on the relation between hypotonia and certain disease syndromes.

The influence of the "veno-pressor mechanism" on the circulation is investigated.

Our thanks are due to Professor E. P. Cathcart, Professor Yandell Henderson, and Professor T. K. Monro for advice, assistance, and access to patients.

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Clinical Memoranda

Acute Puerperal Inversion of the Uterus

Acute inversion of the uterus, one of the rarer complications of labour, is said to occur in England in the proportion of one in about every 200,000 deliveries. While it is impossible to obtain figures for less civilized countries, it may be imagined that the proportion in Central Africa is somewhat higher, since one of the known factors in the aetiology of the condition—namely, traction on the cord—is commonly practised by primitive peoples when the birth of the placenta is delayed.

The patient who is the subject of this note was admitted to hospital on the morning of May 30th, 1936. She was a healthy woman of about 25 years of age and had two children aged 7 and 5 years. There was nothing abnormal in her obstetric record as far as she was aware, and her health during the present pregnancy had been normal. The period of gestation was approximately forty weeks.

Pains had begun "in the middle of the night" (it being impossible to determine the exact hour in the absence of clocks in native huts), and had been of average intensity and frequency. At sunrise (about 6 a.m.) the membranes ruptured, and the baby was born immediately, vertex presentation. The placenta not being born within a short time, the attendant native woman had exerted traction upon the cord until the placenta was delivered. The delivery of the placenta was followed by a brisk haemorrhage, which, however, ceased spontaneously within a few minutes. During the next half-hour a swelling gradually appeared at the vulva, and then presented outside the vulval orifice. In accordance with native custom in any abnormal circumstances, the extruding part was liberally sprinkled with leaves and grass, and an attempt was made by the native women to press back the extruded organ. This attempt had succeeded only in rendering more oedematous the prolapsed parts and in tearing the epithelium in one or two places. The patient was then hurriedly brought from her village to the hospital.

On examination soon after 8 a.m. I found that the general condition of the patient was fairly good despite her clinical state and the drastic treatment to which she had recently been subjected. Her extremities were rather cold, but the pulse and blood pressure gave no cause for undue concern. The uterus was just palpable behind the symphysis pubis through the very lax anterior abdominal wall. The external os could be seen outside the vulva as a very oedematous ring of tissue, purple in colour, and bleeding slightly posteriorly where the epithelium had been abraded. Within the cervix the uterine wall could be seen prolapsed, with its characteristic

fleshy rugae. An extent of about three inches of the anterior (inner) surface of the posterior wall of the uterus was thus visible, including a portion of the placental site at its upper limit.

In view of the good general condition of the patient and the possibility of the cervical tissues becoming more oedematous, I decided to attempt early replacement of the parts. Under chloroform anaesthesia the toilet of the vulval region was performed, and a brisk lysol douche given to remove grass and leaves adherent to the inner surface of those parts of the maternal passages visible outside the vulva. The cervical tissues were then carefully and gradually compressed in order to express some of the oedema, and gentle pressure was exerted on the cervix and on the wall of the uterus. After about fifteen minutes of steady taxis the parts resumed their normal relation. The operation concluded with a hot lysol douche and an injection of pituitary extract to promote optimum uterine retraction. A firm binder was placed around the abdomen and thighs, and the ankles tied together to prevent abduction of the legs. The patient stood the operation well, and was only slightly shocked on leaving the theatre.

The post-partum history was uneventful, the lochia being normal in appearance, quantity, and duration, and the temperature never rising above 99° F. Subsequent vaginal examination during the second week revealed no abnormality: involution had proceeded in normal fashion, and the uterus was normal in form, size, and position, and did not prolapse on straining. When she left hospital with her six and a half pound male child, the mother appeared none the worse for having experienced one of the rarest complications of labour.

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Complete Repair of "Mallet Finger"

This case may be of interest as one of complete repair following the condition of "mallet finger." The prognosis here is by no means good; complete return of function but rarely occurs, the tendon usually uniting in an overlenghtened condition.

Some weeks ago, while casualty house-surgeon at St. Bartholomew's Hospital, I suffered an accident to my right hand, which resulted in the tearing of the insertion of the extensor tendon of the index finger, the condition of "mallet finger" (or "baseball finger" as it is termed in America) immediately developing. The diagnosis was confirmed by an orthopaedic surgeon.

The finger was at once radiographed to eliminate injury to the bone, and was then put in an emergency splint to prevent tension on such fibres of the extensor tendon as (it was hoped) were still intact. Two days later a light aluminium splint of the "thimble" pattern was made, and this maintained the terminal phalanx in as great a condition of hyperextension as was possible. This splint was worn continuously for six weeks without its ever being removed, merely being covered with a rubber finger-stall when I wished to wash or protect it in any way.

At the end of six weeks this splint was removed. Stiffness passed off after three days of gentle movements of the terminal interphalangeal joint, and by the end of a week the movement of the finger was normal. A tendency was noticed, however, for the finger to assume a slightly flexed condition towards the end of the day, so for the first two weeks following its original removal I took to wearing the splint again at night. The present condition of the finger is such that it is normal in every way as compared with the other hand.

The lesson to be learnt from this is, I think, that a poor result in these cases must usually be due to lack of co-operation on the part of the patient and failure to carry out the instructions of the surgeon in every detail. I attribute the whole success of this treatment to maintaining complete hyperextension of the joint continuously for six weeks.

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