noted. The association between murmur and dyspnoea had been shown previously.

The triad of murmur, dyspnoea, and enlargement occurred in full-term babies after birth asphyxia and in premature babies whether they had been asphyxiated at birth or not. Both enlargement and the murmur were early phenomena in babies with dyspnoea.

This association, coupled with the apparent paradox of a slow heart rate in the presence of severe dyspnoea, and related to evidence of a limited ability in the newborn to increase cardiac output, led to the suggestion that cardiac insufficiency was present from an early stage.

Necropsy findings in the lung could be interpreted on the basis of vascular congestion. The early radiological appearances could mean that congestion and oedema were developing.

The suggestion was therefore made that insufficiency on the left side of the heart was the cause of pulmonary congestion and the subsequent symptoms. Asphyxia during birth brought this about in the full-term baby. In the premature child born without asphyxia a defective respiratory mechanism had to be presupposed.

The implications of these views for management were mentioned.

I am indebted to the obstetric staffs of the Paddington General and St. Mary's Hospitals for permission to make observations, and to the midwives and radiographers of both hospitals for help in carrying them out; to Dr. E. Rohan Williams and Dr. R. E. Lawrence for the use of their radiological reports; to Dr. David Symers for the random check in measurements; and to Dr. R. Lightwood, who is in charge of the Paediatric Unit, St. Mary's Hospital Medical School.

REFERENCES

- Ahvenainen, E. K. (1958). *Ann. Paediat. Fenn.*, **4**, 69.
 Arey, J. B., and Dent, J. (1953). *J. Pediat.*, **42**, 205.
 Bakwin, H., and Bakwin, R. M. (1935). *Amer. J. Dis. Child.*, **49**, 861.
 Bauman, W. A., and Nadelhaft, J. (1958). *Pediatrics*, **21**, 813.
 Berfenstam, R., Edlund, T., and Zettergren, L. (1958). *Acta paediat. (Uppsala)*, **47**, 82.
 Blystad, W. (1956). *Acta Paediat. (Uppsala)*, **45**, 103.
 — Landing, B. H., and Smith, C. A. (1951). *Pediatrics*, **8**, 5.
 Bonham Carter, R. E. (1957). *Lancet*, **1**, 1292.
 Born, G. V., Dawes, G. S., and Mott, J. C. (1955). *J. Physiol.*, **130**, 191.
 Bound, J. P., Butler, N. R., and Spector, W. G. (1956). *Brit. med. J.*, **2**, 1191.
 Briggs, J. N., and Hogg, G. (1958). *Pediatrics*, **22**, 41.
 Burnard, E. D. (1959). *Brit. med. J.*, **1**, 134.
 Caffey, J. (1956). *Pediatric X-ray Diagnosis*, 3rd ed. Year Book Publishers, Chicago.
 Claireaux, A. E. (1953). *Lancet*, **2**, 749.
 — (1958). In *Modern Trends in Paediatrics* (2nd series), edited by A. Holzel and J. P. M. Tizard. Butterworth, London.
 Cross, K. W., and Dawes, G. S. (1959). In press.
 Donald, I., and Steiner, R. E. (1953). *Lancet*, **2**, 846.
 Duran-Jorda, F., Holzel, A., and Patterson, W. H. (1956). *Arch. Dis. Childh.*, **31**, 113.
 Ellis, K., and Nadelhaft, J. (1957). *Amer. J. Roentgenol.*, **78**, 444.
 Emery, J. L. (1956). *Lancet*, **1**, 405.
 Farber, S., and Wilson, J. L. (1933). *Amer. J. Dis. Child.*, **46**, 572.
 Feinberg, S. B., and Goldberg, M. E. (1957). *Radiology*, **68**, 185.
 Gilin, D. (1957). *Pediatrics*, **19**, 657.
 Himwich, H. E. (1953). In *Prematurity, Congenital Malformations, and Birth Injury*. Association for the Aid of Crippled Children, New York.
 James, L. S., and Rowe, R. D. (1957). *J. Pediat.*, **51**, 5.
 Jäykkä, S. (1957). *Acta Paediat. (Uppsala)*, **46**, Suppl. 112.
 — (1958). *Ibid.*, **47**, 484.
 Karlberg, P., Cook, C. D., O'Brien, D., Cherry, R. B., and Smith, C. A. (1954). *Acta Paediat. (Uppsala)*, **43**, Suppl. 100, p. 397.
 Kjellberg, S. R., Rudhe, U., and Zetterström, R. (1954). *Acta radiol. (Stockh.)*, **42**, 173.
 Latham, E. F., Nesbitt, R. E. L., and Anderson, G. W. (1955). *Bull. Johns Hopk. Hosp.*, **96**, 173.
 Lendrum, F. C. (1955). *J. Pediat.*, **47**, 149.
 Lind, J., and Wegelius, C. (1954). *Cold Spr. Harb. Symp. quant. Biol.*, **19**, 109.
 Martin, J. F., and Friedell, H. L. (1952). *Amer. J. Roentgenol.*, **67**, 905.
 Mayer, M. (1953). In *Anoxia of the Newborn Infant*. Blackwell, Oxford.
 Miller, H. C., and Wilson, H. M. (1943). *J. Pediat.*, **23**, 251.
 Nadas, A. S. (1947). *Pediatric Cardiology*. Saunders, Philadelphia.
 Norris, R. F., Kochenderfer, T. T., and Tyson, R. M. (1941). *Amer. J. Dis. Child.*, **61**, 933.
 Parmelee, A. H. (1952). *J. Pediat.*, **41**, 591.
 Peterson, H. G., and Pendleton, M. E. (1955). *Amer. J. Roentgenol.*, **74**, 801.
 Potter, E. L. (1952). *Pathology of the Fetus and the Newborn*. Year Book Publishers, Chicago.
 — (1953). *Advanc. Pediat.*, **6**, 157.
 Steiner, R. E. (1954). *Brit. J. Radiol.*, **27**, 491.
 Swyer, P. D. (1958). *Canad. med. Ass. J.*, **78**, 239.
 Van Breemen, V. L., Neustein, H. B., and Bruns, P. D. (1957). *Amer. J. Path.*, **33**, 769.
 Winter, W. D., and Gellis, S. S. (1954). *Amer. J. Dis. Child.*, **87**, 702.
 Zetterström, R. (1955). *Acta Paediat. (Uppsala)*, **44**, Suppl. 103, p. 72.

ECHO-ENCEPHALOGRAPHY*

ULTRASONIC RAYS IN DIAGNOSTIC RADIOLOGY

BY

DOUGLAS GORDON, M.B., Ch.B., D.M.R.

Radiologist, West End Hospital for Neurology and
 Neurosurgery, Moorfields Eye Hospital, and
 Willesden General Hospital

Galton described his ultrasonic whistle in 1883, but, apart from signalling to dogs, no practical use seems to have been made of ultrasonic rays until the war of 1914–18. At that time pulses of ultrasonic rays were transmitted through water as a means of detecting and locating submarines. Since then it has become standard practice to employ ultrasonic echoes for measuring the ocean depth and to detect icebergs.

Since the second world war the same principles have been applied in the industrial field, particularly for the detection of flaws in large masses of metal. Dussik (1948) published a paper on the medical use of ultrasonic rays, but using continuous radiation. The patient's head was immersed in a water-tank and the absorption of transmitted radiation was measured. This had the obvious disadvantage of the tank and the danger of continuous radiation.

The earliest published work using pulses and echoes in medicine is that of Wild (1950). French, Wild, and Neal (1951) used apparatus developed by the United States Navy for service purposes and called the ultrasonic trainer. Owing to the high frequency of 15 million cycles per second, this apparatus could penetrate only 3 cm. into soft tissue. In consequence it was used mainly to differentiate carcinoma from benign conditions of the breast. Its use on the brain was restricted to patients at craniotomy where the probe could be applied direct to the cortex.

In early 1954 the physics department of the Royal Marsden Hospital demonstrated at the Physical Society's Exhibition a modification of the Kelvin and Hughes flaw-detector, mark IIB, which gave echoes from front to back of the intact skull, using pulses of frequency $1\frac{1}{2}$ Mc. per second.

In 1956 Professor Leksell, of Lund, published his results with the Kelvin and Hughes flaw-detector mark V, which he had used since 1953. Professor Donald, of Glasgow, has been using a specially modified flaw-detector for the differentiation of large abdominal tumours. He

*Based on a lecture given at Newcastle General Hospital for the North-east Regional Board on February 7, 1958.

has an elaborate two-dimensional display and claims to determine the nature of fluid in ovarian cysts and even to distinguish malignant from benign tumours and from pregnancy in some of his cases (Donald, MacVicar, and Brown, 1958).

I demonstrated the method at the Symposium Neuroradiologicum in London in 1955, and at the next symposium in Brussels in 1957 demonstrated the improved apparatus that is the subject of this paper.

Physical Principles

The Curie brothers in 1880 observed the piezo-electric effect. This is the production of an electrical charge on opposing surfaces of a crystal when it is under stress. There is a direct proportion between the charge and the stress. The polarity reverses on changing from tension to compression. In 1881 Lippman predicted the reverse piezo-electric effect, that an electric charge applied to opposing surfaces of a crystal would produce a mechanical strain within it.

At the frequencies employed in medicine the ultrasonic rays are produced by crystals of quartz or barium titanate. These are of the order of 1 to 3 sq. cm. in area, and the thickness varies inversely with the natural frequency of the crystal.

The crystal acting as a generator is placed in a holder with its surfaces perpendicular to the direction of propagation of the rays. The side nearer the test object or patient is covered with an earthed conducting layer. The other side also has a conducting layer, which is connected to the exciting source by an insulated cable.

Ultrasonic rays are much closer in type to sound waves than to radio or x rays. They are actual movements backwards and forwards of the molecules of the transmitting medium. It follows that they cannot traverse a vacuum. In liquids the direction of propagation is parallel to the excursion of the molecules.

The production of echoes depends on the rays traversing an interface between two media in which the velocities of the rays differ. The factors affecting the velocity of propagation are very complex, but include the density and the elasticity. Though the densities of cerebrospinal fluid and brain are almost identical, there is considerable difference in their elasticities, and it is possible to obtain echoes from the surface of the brain without employing an artificial contrast medium.

On the other hand, the great difference between the densities of air and cerebrospinal fluid causes such a difference in the velocities that almost complete reflection of ultrasonic rays occurs at any interface between them. In practice this means that the thinnest film of air will obstruct the rays completely.

Another function met in both sound and ultrasonic rays is reverberation. This is where the rays are reflected backwards and forwards between parallel surfaces, giving multiple echoes each smaller than its predecessor. Ultrasonic rays are also refracted and diffracted in accordance with known laws.

If the crystal generator has a concave emitting surface the rays will focus to a point at the centre of curvature. This allows high intensities to be attained at a depth in brain tissue, leaving the surface layers unaffected.

To achieve cell damage it is necessary to excite the crystal continuously with a power of the order of watts per square centimetre for several minutes with no intervening bone.

In the diagnostic applications using echoes the crystal is energized with a power measured in microwatts, the rays are always diverging instead of being focused, and excitation lasts for a few microseconds every fiftieth of a second.

Apparatus

Basically the Kelvin and Hughes flaw-detector, as modified for medical use, consists of the following items (Fig. 1): (1) a device for generating repeated short pulses of radiofrequency energy to excite the transmitting crystal; (2) a matched pair of transmitting crystals in holders with cables and a common matching transformer; (3) a matched pair of receiving crystals in holders with cables and a common matching

FIG. 1.—Kelvin and Hughes flaw-detector mark V fitted with comparator on the side and special camera with angled mirror.

transformer; (4) an amplifier and detector circuit; (5) a cathode-ray oscilloscope; (6) a time-base linked with both 1 and 5; (7) a comparator circuit linked with 1, 2, and 5; and (8) a single shot camera if permanent records are required.

For medical purposes pulses are produced every fiftieth of a second by triggering a thyatron at mains frequency. The energizing voltage of the thyatron is also preferably continuously variable.

The sudden pulse of energy from the thyatron is converted into oscillations of the selected radio-frequency by a tuned circuit, and these excite the crystal directly, if of quartz, or after stepping down in the case of barium titanate.

The amplifier is preferably of the "video" type, but where only one frequency is used it is possible to increase the sensitivity greatly by employing tuned circuits "staggered" to pass a band of several hundred kilocycles.

Echoes returning from reflecting surfaces to the receiving crystal produce radio-frequency electrical pulses of the order of microvolts. These are greatly amplified and then rectified and partly smoothed so that they are normally displayed on the oscilloscope as upward deviations of the trace.

As the time intervals between the transmitting pulse and the echo are proportional to the distance travelled in the comparatively uniform medium of the human head, the distance between the reflecting surface and the crystals is proportional to the distance between the

deviations of the oscilloscope trace. It is, however, possible to suppress the earlier part of the trace and to expand the remaining part.

Professor Leksell drew my attention to the difficulty of making accurate comparisons between the two sides of the head when they were examined *seriatim*. The suggestion was made that the two sides should be examined *simulativim*. Acting on this suggestion, I designed and perfected the comparator as an addition to the flaw-detector.

The Comparator

The comparator is in effect a high-speed changeover switch. It necessitates the use of two transmitting and two receiving crystals. These are usually employed in the form of "V.L.O." probes, which comprise one transmitting and one receiving crystal close together in the same plane but acoustically screened from one another. In the right or normal position of the switch the pulses are transmitted to and the echoes received from the probe on the right side and the signals are displayed as deviations upwards. In the left position the pulses are transmitted to and the echoes received from the left probe, but the deviations are downwards. While one probe is in use the other is disconnected. As a mnemonic the upper right trace comes from the right red probe, while the lower left trace comes from the blue left probe.

The changeover switch is synchronized with mains frequency so that usually two consecutive traces are recorded from one side, followed by two from the other. The screen persistence is sufficient to prevent flicker with a $12\frac{1}{2}$ c.p.s. changeover rate. With the comparator it is possible to detect asymmetries of less than 1 mm.

It is now possible to employ the same crystal as both transmitter and receiver without sacrifice of too much sensitivity.

Echo Patterns

The best method of studying echo patterns is to use a phantom in the form of a tank of water in which test objects may be placed. At first simple geometrical shapes are employed such as a sphere, a flat surface, or a wire. When familiarity has been attained with such simple reflecting surfaces it is desirable to employ a brain floating entire and with air excluded from its interior.

The first lesson learnt is that good echoes are readily recorded from quite small flat surfaces when they are perpendicular to the rays, but quite small deviations from the perpendicular greatly attenuate the signals. On the other hand, in a uniform medium such as water there is hardly any attenuation for large variations in distance.

Even as fine a wire as 0.14 mm. will give a good echo when its long axis is parallel to the crystal, even though the wavelength of the rays is 1.16 mm. in water at $1\frac{1}{2}$ Mc., which is the frequency employed. As each pulse consists of several waves it is possible to record two separate echoes if the distances differ by about 5 mm. but not less.

Practical Problems in Medical Use

The structure of the skull vault is such that a very large proportion of the energy is lost by dispersion both during transmission of the pulse into the cranial cavity and during the return of the echo. This dispersion is

least when a crystal is tangential to the surface but increases rapidly with any tilting. The dispersion is greater with the shorter wavelengths and in practice $1\frac{1}{2}$ Mc. has proved to be the upper limit of frequency for work involving the adult skull. The flat surface of a "perspex" tank has very little effect of this type, so that much better echoes are obtained from a brain in a water-tank than *in vivo*. The interposition of a bone fragment between tank wall and brain restores the attenuation to that found *in vivo*. A specimen of dried bone retains so much air between the tables that it is impenetrable.

To exclude air between the probe and the skin some coupling medium is required. Leksell uses liquid paraffin, but I find that a water-base jelly made from "polycell" more closely approximates to tissue acoustically. This material consists of a mixture of ethers and esters of cellulose and is normally sold as a fixative: 2.5 g. dissolved in 40 ml. of water will produce a jelly of satisfactory consistency.

With an approximately spherical surface such as the skull vault, it is obviously easier to obtain tangential application of two crystals that are in the same plane if they are small. Unfortunately the sensitivity diminishes with the size while the directionality of the beam deteriorates.

The V.L.O. probe contains two barium titanate crystals each 20 by 10 mm. and the perspex block that has to be applied has an area of 45 by 40 mm. This limits its use to the flatter parts of the skull such as the temples and forehead. However, the latest developments employing a single crystal for both transmitting and receiving, coupled with further improvements in the amplifiers, give promise in the near future of a much smaller probe surface without loss of sensitivity. This applies particularly to the skull, where a loss of signal for the first centimetre, due to blocking of the amplifiers, is not of importance.

The falx and the tentorium present ideal surfaces for reflection, but owing to their situation relative to the scalp it has not so far proved possible to produce echoes from either.

All workers are agreed that the largest echo recorded from the skull is to be found with a temporal placing of the probe, and it arises from a structure in the midline in normal subjects. I have always considered this to arise from the septum pellucidum, but recently Leksell (1958) has attributed it to the pineal body. Experiments recently carried out establish that the septum pellucidum is much more likely to be the source of the echo than is the pineal.

The directionality of the rays differs greatly with the size and shape of the crystals and the frequency of excitation. With experiments *in vivo* the problem of the vault ensures that the largest echo is not necessarily obtained when the probe is opposite the structure. This is avoided by using the water-tank, in which the brain may be moved freely relative to the probe.

It will be found that the largest midline echo is obtained by placing the probe opposite the lower end of the central sulcus (Rolando). This, admittedly, is compatible with either the posterior part of the septum or the pineal as the origin of the echo. If, however, the brain is tilted slightly in both axes it will be found that the amplitude of the echo will be reduced to half by a tilt of the order of 5 degrees either side of the position giving the largest echo.

If the brain is replaced by a flat surface in the exact plane formerly occupied by the septum and pineal it will be found that it will show a similar variation with a tilt of about 2 degrees either side of maximum.

If, however, a spherical object is placed at the same point it naturally shows no change whatever with rotation to any extent. These observations seem to establish that the large midline echo is much more likely to be due to an almost flat surface like the septum pellucidum than to an approximately spherical structure such as the pineal.

The suggestion is made that the diminution of the midline echo from the larger anterior part of the septum is due to the fact that here the incident rays strike the outer surface of the brain less perpendicularly and attenuation occurs there. Similarly, *in vivo* the skull vault is traversed more favourably when the probe is opposite the posterior part of the septum than when it is placed anteriorly.

Where the third ventricle is of greater width than average it is possible to obtain echoes from both walls, but if it is narrow the echo is indistinguishable from the septum echo (Fig. 2).

With increasing sensitivity of probes and amplifiers it is certain that echoes from the roof of the lateral

ventricle will be obtainable soon, and, using the comparator, homologous areas will be directly comparable. Later the distances to the convexity should also be directly comparable.

Mundt and Hughes (1956) have employed echo techniques in detecting tumours and detachments of the retina. This would benefit from comparison of the two eyes.

In other parts of the body, such as the pleura, the comparator should prove of value, but owing to their air-content the lungs cannot be penetrated. It should prove of value in detecting collections of fluid within layers of pleural exudate, and it should detect even the smallest layer of air over an abscess prior to exploration.

Effert, Erkens, and Grosse-Brockhoff (1957) and Effert and Domanig (1959) have applied echo techniques to the heart but are restricted to the bare area for access owing to the impenetrability of lung. They are, however, able to obtain a record of heart movement by using moving film rather after the manner of early electrocardiography.

Risks of Echo-Encephalography

The well-known technique for destroying brain tissue by ultrasonic rays has caused much prejudice against their diagnostic use even though the energy level is greatly less and the rays are attenuated by the skull. In order to obtain reassurance on this point experimental work on cats was performed at the department of anatomy of University College.

A large crystal was applied to one side of a cat's skull, and this was excited at almost double the voltage and three times the repetition frequency used medically. Irradiation was continued for five minutes.

It was not possible to detect any evidence of damage when the brain was sectioned after a suitable interval. As the skull of the cat is so much thinner than that of man, the risk of irradiation under the conditions now employed appears to be extremely small. Further tests are, however, to be arranged to establish exactly how great the factor of safety is.

Discussion

Jefferson (1959), employing the mark V flaw-detector modified for medical purposes and fitted with a comparator, has already reported a considerable series of cases with encouraging results. With further improvements in probe design and longer experience it should be possible to extend the area of the scalp from which useful signals can be obtained with reliability.

At present the method may be said to have shown the possibility of rapidly obtaining evidence of displacements of the brain without disturbance or risk. This is of particular value in severe head injuries and in examining patients in places where angiography or pneumography is inadvisable. It also provides a method of observing the progress of inoperable or post-operative cases more often than is practicable with x rays.

Summary

The uses of pulses of ultrasonic rays in medical diagnosis are reviewed and a comparator permitting the simultaneous use of two ultrasonic probes is described.

The large echo obtained from the midline of the brain is attributed to the septum pellucidum rather than to the pineal body.

FIG. 2.—Trace obtained with right probe opposite septum and left probe opposite third ventricle. a=Complex echoes from scalp and bone. b=Echo from lateral wall of right lateral ventricle. c=Echo from septum pellucidum. d=Echo from lateral wall of left lateral ventricle. e=Echo from left wall of third ventricle. f=Echo from right wall of third ventricle. g=Echo from inner table of right temporal bone.

I wish to acknowledge the great help given by Messrs. Kelvin and Hughes, Ltd., Barkingside, Essex, who have lent the apparatus employed and provided other facilities. Acknowledgment is also made to the anatomy department of University College for carrying out the animal experiments and to Dr. F. D. Bosanquet for making histological examinations.

REFERENCES

- Donald, I., MacVicar, J., and Brown, T. G. (1958). *Lancet*, **1**, 1188.
 Dussik, K. T. (1948). *Z. phys. Ther.*, **1**, 140.
 Effert, S., and Domanig, E. (1959). *Germ. med. Monthly*, **4**, 1.
 — Erken, H., and Grosse-Brockhoff, F. (1957). *Ibid.*, **2**, 325.
 French, L. A., Wild, J. J., and Neal, D. (1951). *Cancer*, **4**, 342.
 Jefferson, A. (1959). *J. Neurol. Neurosurg. Psychiat.*, **22**, 83.
 Leksell, L. (1956). *Acta chir. scand.*, **110**, 301.
 — (1958). *Ibid.*, **115**, 255.
 Mundt, G. H., and Hughes, W. F. (1956). *Amer. J. Ophthalm.*, **41**, 488.
 Wild, J. J. (1950). *Surgery*, **47**, 183.

RESPONSE TO STRETCH OF HYPERTONIC MUSCLE GROUPS IN HEMIPLEGIA*

BY

J. BREWSTER BRENNAN, M.D., D.Phys.Med.
*Department of Physical Medicine, St. James's Hospital,
 London*

A chance observation provided the stimulus for the work presented. A man with hemiplegia of one year's duration was fitted with a splint to prevent contracture of his knee, which was habitually held in 90 degrees flexion by marked tonic spasm. The splint held his knee in full extension. Next seen a month later, he gave the history that he had worn it constantly during that time. He had found it comfortable to wear and it had enabled him to walk, so he had not risked its removal, fearing his spasm might return. On examination of the limb it was found that hypertonus in the hamstrings had been abolished and that voluntary extension, previously absent, could be performed against resistance. Tonus in the quadriceps, originally mild, had become appreciable, but voluntary flexion had not been much affected.

He had had no other treatment during that month, and it seemed probable that this new distribution of tonus in the flexors and extensors of the knee was a result of stretching the former and shortening the latter constantly for such a long time. It was a most desirable change, since it enabled him to walk. On the other hand, his case was unusual in that the knee flexors had originally shown a degree of hypertonus much more commonly found in the knee extensors and in the flexors of the peripheral joints of the upper limb. It was thought that if the same change could be produced in the muscles of the upper limb by similar means a useful therapeutic measure might be established. The considerable power which the flexors often possess is of little functional value when the joints cannot be voluntarily extended.

Material and Methods

Fourteen hemiplegic patients were selected and the response to stretch of 19 flexor muscle groups—18 in the upper limbs and 1 in the lower—was studied over a period of three years. The average duration of hemiplegia before beginning treatment was 18 months.

*This work is based on part of the material submitted for the M.D. examination, University of Glasgow.

Selection of Patients.—The following were the criteria used: the duration of the hemiplegia exceeded six months, its onset had been sudden, and was presumably of cerebrovascular origin; the musculature of the affected side presented constant tonic spasm; no improvement in active movement; and no lessening of tonus had been noted for a minimum period of four weeks. Some authorities (Lowman, 1948; Brain, 1955) have suggested that the period of spontaneous recovery of movement or decrease in hypertonus does not extend beyond the end of the third month after onset. Twitchell (1951), in his study of the natural course of hemiplegia, found that postural abnormality disappeared within 43 to 60 days in recovering cases. However, to avoid error with more certainty, six months was selected as signalling the end of natural improvement.

Controls.—The changes in the stretched flexor muscle group and in its shortened antagonist group were compared with those in the corresponding (untreated) groups controlling a neighbouring joint.

Treatment.—In each patient one or more flexor muscle groups, habitually held in a state of contraction by tonic spasm, were subjected to stretch by keeping the appropriate joint extended in a splint. This was maintained for a long period, usually about three months, during which time the splint was removed only long enough to wash the part twice each day. The patients were encouraged to move the joint actively during these free periods. Once flexion spasm had been abolished and an increased range of active extension established for at least a month the appliance was worn for progressively shorter daily periods and finally discarded. No other form of treatment was prescribed while the muscles were being stretched or during the follow-up period.

Examination.—To provide reliable results an accurate clinical method of measuring change in the degree of tonus and change in the range and power of active movement was required. An attempt was made to elaborate an acceptable method. A standard examination procedure was used at each examination; factors known to influence tonus and contractility, such as temperature, attitudinal reflexes, flexion and extension synergies, were also standardized on each occasion. Space does not permit full documentation of the examination technique, but it is necessary to describe one of its parts in order to make clear the section of results dealing with the effect of stretch on hypertonus. One of the ways in which decrease in flexor muscle tonus made itself evident was that the arc of passive movement from the position of full flexion towards the position of extension during which no resistance could be felt was found to progressively increase. The difference between the length of this arc before stretch began and the length when it was stopped is recorded in the results. Commonly the amount of this increase was such that the joint could be fully extended without resistance.

Results

The change in flexor tonus, measured by the change in range of unresisted passive extension movement at the end of the period of stretch, is shown in the Table (A 1). The spontaneous change in tonus occurring in the control flexor group, also measured at the end of that period, is also shown (A 2). As tonus in the stretched flexor group became reduced to normal the