Paraesthesiae consequent on peripheral nerve compression or general limb ischaemia have long attracted interest, and many features suggest their possible value in the study of peripheral nerve disorders. However, it is not certain if they are an essential feature of normal nervous function or if any significance can be attached to their absence. To clarify this and to determine features suitable as criteria of normality in the clinical application of paraesthesiae tests, the responses produced by a standard test have been studied in normal subjects of different ages. This showed that age appeared to modify the response, and the results are reported here.

The usual method of eliciting paraesthesiae is by occlusion of the circulation with a sphygmonanometer cuff applied above the elbow. During such a procedure ischaemic paraesthesiae (I.P.) appear within a minute or so as faint tingling, buzzing, or vibrating sensations in the hand spreading a variable distance up the limb before dying away some minutes later (Kugelberg, 1944; Weddell and Sinclair, 1947). On releasing the cuff post-ischaemic paraesthesiae (P.I.P.) follow (Lewis, Pickering, and Rothschild, 1931; Zotterman, 1933; Kugelberg, 1944; Weddell and Sinclair, 1947). Four elements have been distinguished (Merrington and Nathan, 1949)—thermal, pseudo-cramp, tingling, and prickling—but the present study concerns only the last two to which the term P.I.P. is here restricted. These form the prominent pins-and-needles sensation which appears distally in the hand approximately one minute after circulatory release and persists for some minutes. The presence, intensity, and duration of P.I.P. are determined by the length of provocative occlusion at any site; upper arm occlusions of seven minutes (or even less) have been found usually adequate to produce P.I.P. in previous studies. Post-ischaemic paraesthesiae, unlike I.P., require a standard period of ischaemia for any comparative assessments, and it seemed of importance in the present study to employ an occlusion normally adequate but sufficiently short to be generally tolerable (even in pathological states) and with the minimum of risk of ischaemic damage. An important associated feature of post-ischaemic responses also considered in this study is post-ischaemic muscle twitching (Reid, 1931). This occurs predominantly in the small muscles of the hand where it provides objective evidence of responses analogous to P.I.P. though less readily induced (Kugelberg, 1944, 1946, 1948; Magladery, McDougal, and Stoll, 1950; Kugelberg and Cobb, 1951).

Material and Methods

Subjects.—Two series of subjects were examined.

Series I.—This series comprised 93 normal subjects examined by a standard procedure with occlusion for 10 minutes, as described below. These were either healthy volunteers or convalescent patients free from any possible relevant defect. For inclusion they had to be (1) average or better witnesses; (2) normotensive (casual systolic pressure not exceeding 180 mm. Hg); (3) not anaemic clinically (haemoglobin level not less than 75%); and (4) with warm limbs, the interdigital cleft temperature being not less than 80° F. The ages ranged from 12 to 84 years, with average 44.6, and they were considered in four groups thus:

Group A (age 12 to 30 years)—24 subjects with average age 22.2 years.
Group B (age 31 to 45 years)—25 subjects with average age 38.2 years.
Group C (age 46 to 60 years)—25 subjects with average age 53.1 years.
Group D (age 61 to 84 years)—19 subjects with average age 70.1 years.

The sex ratio was 4 : 1 in favour of males.

Series II.—This series comprised an approximately equal number of subjects, free from sensory abnormality but excluded from Series I on the following grounds: (a) the presence of anaemia, hypertension, or cold limbs as detailed above; (b) a test not of the standard 10-minute type, or not assessed in full detail; and (c) the
ISCHAEMIC AND POST-ISCHAEMIC PARAESTHESIAE

presence of non-sensory abnormalities from manifest nervous disease. The broad details of the responses in this heterogeneous series of normals and “probable” normals provided additional evidence of general trends and allowed some assessment of the influence of various factors such as anaemia.

Standard Paraesthesiae Test.—A standard period of ischaemia was arbitrarily fixed as 10 minutes of complete circulatory arrest from an above-elbow compression. This allowed adequate time for the elicitation of P.I.P., and was longer than that usually needed for the production of P.I.P.; and though pricking and tingling might not both occur (Merrington and Nathan, 1949), this was not considered important. Such an occlusion was usually readily tolerated, but was nevertheless near the upper limit of endurance in some instances, and was certainly often the greatest to be achieved in relevant pathological states, e.g., polyneuritis. It was adequate to assess any premature ischaemic sensory impairment, and its duration was reassuringly short from the viewpoint of vascular damage in the elderly. Though the lower limb seemed, through its greater susceptibility to both ageing and disease processes, to be a more useful field for study, the discomfort caused by such occlusions and the possibility of vascular damage were effective deterrents.

Examination.—The subjects were examined under warm and quiet circumstances. Sensory or motor symptoms past or present were carefully enquired for as well as the state of general health. The usual clinical assessments of motor, reflex, and sensory functions were augmented by the use of graded nylon hairs to test tactile perception in many instances, and by the use of a tuning fork activated to standard degrees to provide an index of vibration perception. Details as to the blood pressure, the degree of peripheral vascular sclerosis, and the existence of anaemia were noted, and as an index of limb temperature the interdigital cleft temperature was recorded with a Marks skin thermometer.

Limb ischaemia was induced by a sphygmomanometer with a bag of 23 cm. by 12.5 cm. centred over the medial aspect of the limb, its lower border being 3 to 5 cm. above the medial epicondyle. The arm was elevated for approximately 15 to 20 sec.; the cuff was then rapidly inflated to pressures of 180 to 200 mm. Hg; and finally the arm was lowered to rest lightly on a padded table, or by the side if the subject was in bed. The moment of occlusion, its duration, and the onset of sensations were noted on a stop-watch. At the end of the occlusion, the bag was disconnected and removed, the pressure falling at once to zero. In the unusual event of compression causing considerable discomfort, the occluding pressures were reduced to 150 mm. Hg where possible; in the elderly and hypertensives the pressures were increased to 220 to 230 mm. Hg, or at 30 mm. above the systolic pressure. The level of the cuff above the medial epicondyle and the limb calibre at the mid-point of compression were later measured from the zone of hyperaemia. No strict temperature control was employed, but cooling was minimized by examining in a warm room, and in some instances having a source of radiant heat nearby.

Before occlusion the nature of the test was explained to the subject and he was instructed to concentrate on his arm and to report promptly any “feelings” which might arise, even if their precise nature was uncertain. As soon as any sensations were reported their character, distribution, site of onset, preferential reference, and proximal spread were pursued, and attention focused on the time when they had ceased or were not certainly present. If no sensations were reported, general inquiries were made as to the state of the arm every one to two minutes, and if nothing was noted by the latter part of the occlusion, specific questions were asked as to the presence at any stage of feelings of vibrating, buzzing, tingling, burning, or cold, to ensure that nothing was overlooked.

On circulatory release a similar procedure was followed. Questions as to the state of the limb were put approximately every half-minute and, when no pins-and-needles was reported after one and a half to two minutes, peripheral stimuli of squeezing and tapping of the fingers known to aggravate P.I.P. (Lewis and others, 1931; Weddell and Sinclair, 1947) were used to ascertain if any impressions could be evoked. Finally, if no sensations were reported after three minutes, the presence of pins-and-needles, buzzing, thrusting, or throbbing at any stage was directly sought to ensure that the subject was not neglecting to report them. The influence of the above peripheral stimulation on P.I.P. was noted from time to time and used to ensure that impressions could not be re-induced after their reported cessation. Later the test was discussed in retrospect and comparisons made between the ischaemic and post-ischaemic experiences. If any important feature of the responses was in doubt the test was repeated on the opposite limb and or on the same limb after an interval of at least 24 hours. In many cases observations were made on the degree of unprovoked post-ischaemic muscle twitching visible in the first dorsal intersosseous muscle.

Assessment of Responses.—Though the initial aim was merely to record the presence or absence of some form of tingling or pins-and-needles with the standard test, it became apparent that more detailed assessments of the precise time-course of the responses might be of value. Previous workers have used both the time of onset and the duration as indices of the severity of the responses with P.I.P. (and to some extent with I.P.), more intense reactions being associated with more rapid onset and longer duration. The onset of P.I.P. was abrupt and I.P. moderately so with appreciable sensations, but their cessation was more insidious especially for I.P. Where doubts arose, the end-point was taken as the mean between certain presence and absence, but no weight was placed on minor changes in I.P., and for the more definite P.I.P. the end-point was usually relatively clear, no appreciable alteration being produced by this refinement. For general analysis the times were listed to the nearest 0.1 minute.

In addition to the time-course of the responses some
crude assessment of their maximum intensity was attempted on a " + " system of grading. For I.P. this was:

- (+) = faint impressions of "something going on"
- (+++) = obvious but not moving the finger
- (++++) = very severe

For P.I.P. the grading was thus:

- (+) = only mild tingling, even with peripheral stimulation
- (+++) = "real pins-and-needles", prominent sharp sensations
- (++++) = pins-and-needles causing frank distress without peripheral stimulation

A distinction was made between I.P. and vague impressions which appeared to be purely thermal, though if the latter were prominent in the early stages of occlusion and especially if localized to any area of the hand, they were classed as "doubtful" provided all intermittent vibrating, tingling qualities were denied. In the post-ischaemic phase a distinction between pricking and tingling was attempted only in so far as estimating whether any sharp pricking pins-and-needles was present at any time.

Assessments of induced muscle twitching were based on the maximum visible unprovoked activity at any stage in the small muscles of the hand, crudely graded thus:

- (+) = just visible
- (+++) = considerable with evident finger movements
- (++++) = striking with gross finger movements

Results

Series I.—These results were found in normal subjects.

**Ischaemic Paraesthesiae.**—The analysis of the results for I.P. appears in the Table at (a). The incidence of occurrence has been given in three classes, "definite", "doubtful", and "absent"; "doubtful" indicates vague or inconstant impressions, possibly purely thermal. In the youngest group (A) definite responses were always obtained, but in the oldest group (D) these occurred in little more than one-third of the subjects. This decreasing trend of response with age was also shown in the plus intensity grading, and further, where distinct impressions were present in the older groups, the mean onset was slightly delayed, a change to be expected with less intense responses (Kugelberg, 1944, 1948). Though the mean duration of the definite I.P.

### Table

<table>
<thead>
<tr>
<th>Age Group</th>
<th>A (12-30 yr.)</th>
<th>B (31-45 yr.)</th>
<th>C (46-60 yr.)</th>
<th>D (61-84 yr.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of Subjects</td>
<td>24</td>
<td>25</td>
<td>25</td>
<td>19</td>
</tr>
<tr>
<td>(a) Ischaemic Paraesthesiae</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incidence of I.P.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Definite</td>
<td>24 (100%)</td>
<td>18 (72%)</td>
<td>18 (72%)</td>
<td>7 (37%)</td>
</tr>
<tr>
<td>Doubtful</td>
<td>0 (0%)</td>
<td>1 (4%)</td>
<td>4 (16%)</td>
<td>1 (5%)</td>
</tr>
<tr>
<td>Absent</td>
<td>0 (0%)</td>
<td>6 (24%)</td>
<td>3 (12%)</td>
<td>11 (58%)</td>
</tr>
<tr>
<td>Mean intensity (+ grading)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All subjects</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>&quot;Definitions&quot;</td>
<td>1-9</td>
<td>1-4</td>
<td>1-1</td>
<td>0-5</td>
</tr>
<tr>
<td>Onset (min.) after occlusion in those with definite I.P.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean and (S.D.)</td>
<td>1-4 (0-42)</td>
<td>1-5 (0-58)</td>
<td>2-1 (1-00)</td>
<td>1-8 (0-56)</td>
</tr>
<tr>
<td>Limits</td>
<td>0-8-2-5</td>
<td>0-5-2-8</td>
<td>0-8-3-5</td>
<td>1-0-2-5</td>
</tr>
<tr>
<td>Duration (min.) of definite I.P. (to limit of occlusion)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean and (S.D.)</td>
<td>6-1 (1-66)</td>
<td>6-4 (2-05)</td>
<td>5-5 (1-55)</td>
<td>6-0 (2-90)</td>
</tr>
<tr>
<td>Limits</td>
<td>2-3-9-2</td>
<td>3-0-9-5</td>
<td>3-5-8-7</td>
<td>2-5-9-0</td>
</tr>
<tr>
<td>Nos. with I.P. to or above mid-forearm</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>(b) Post-ischaemic Paraesthesiae</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incidence of P.I.P.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Definite</td>
<td>24 (100%)</td>
<td>25 (100%)</td>
<td>25 (100%)</td>
<td>15 (79%)</td>
</tr>
<tr>
<td>Absent</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
<td>4 (21%)</td>
</tr>
<tr>
<td>Nature: No, with undoubted sharp pricking</td>
<td>24 (100%)</td>
<td>25 (100%)</td>
<td>21 (84%)</td>
<td>7 (37%)</td>
</tr>
<tr>
<td>Mean intensity (+ grading)</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1-1 (all cases)</td>
</tr>
<tr>
<td>% Lacking accentuation by &quot;tapping&quot;</td>
<td>4% (24 assessed)</td>
<td>29% (17 assessed)</td>
<td>51% (19 assessed)</td>
<td>12% (13 assessed)</td>
</tr>
<tr>
<td>Onset (min.) after circulatory release in subjects with P.I.P.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean and (S.D.)</td>
<td>1-0 (0-24)</td>
<td>1-0 (0-26)</td>
<td>1-1 (0-35)</td>
<td>1-4 (0-34)</td>
</tr>
<tr>
<td>Limits</td>
<td>0-6-1-5</td>
<td>0-6-1-5</td>
<td>0-7-2-5</td>
<td>0-9-2-7</td>
</tr>
<tr>
<td>Duration (min.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean and (S.D.)</td>
<td>3-5 (1-80)</td>
<td>4-6 (1-14)</td>
<td>4-2 (1-37)</td>
<td>2-6 (1-64)</td>
</tr>
<tr>
<td>Limits</td>
<td>3-5-11-7</td>
<td>2-3-6-5</td>
<td>2-2-7-1</td>
<td>2-6 (1-64)</td>
</tr>
<tr>
<td>No. with P.I.P. confined to fingers</td>
<td>2 (8%)</td>
<td>3 (12%)</td>
<td>4 (18%)</td>
<td>6 (32%)</td>
</tr>
<tr>
<td>Post-ischaemic muscle twitching</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Present</td>
<td>73%</td>
<td>75%</td>
<td>67%</td>
<td>50%</td>
</tr>
<tr>
<td>Severe</td>
<td>36%</td>
<td>36%</td>
<td>36%</td>
<td>36%</td>
</tr>
<tr>
<td>(22 assessed)</td>
<td>(12 assessed)</td>
<td>(15 assessed)</td>
<td>(14 assessed)</td>
<td></td>
</tr>
</tbody>
</table>
ISCHAEMIC AND POST-ISCHAEMIC PARAESTHESIAE

showed some reduction in the older groups (bearing in mind the small number of "definites" in group D), little weight can be put on this slight change in view of the difficulty in determining precise endpoints with I.P. In the younger groups paraesthesiae more often extended to or above the mid-forearm level, a spread in keeping with their greater intensity (Kugelberg, 1944). In all groups I.P. were often preferentially referred to ulnar but not median nerve territory, as previously described (Weddell and Sinclair, 1947; Gilliatt and Wilson, 1953). There was no evidence for any sex difference in the incidence of occurrence of I.P. when the small female group was considered separately.

Post-ischaemic Paraesthesiae.—The analysis of P.I.P. results appears in the Table at (b). In contrast to I.P., P.I.P. occurred with remarkable constancy, distinct sensations being reported by all subjects except four in the oldest group (D). However, sharp pricking sensations were, as far as could be judged, frequently absent in the older groups, and peripheral stimuli often failed to accentuate the impressions. Moreover, the average intensity based on the plus grading showed a steady decline, all suggesting a diffuse reduction in the response with advancing years. Further, this was clearly evident in the mean onsets and durations, the former increasing and the latter decreasing in the older groups, both in keeping with decreasing intensities of response (Lewis and others, 1931; Zotterman, 1933; Weddell and Sinclair, 1947). The equation of regression of duration of P.I.P. with age was

\[ y = 6.43 - 0.049 \times \]

where \( y \) = duration of P.I.P. in minutes and \( x \) = age in years. The regression was highly significant (standard error of regression coefficient = 0.009 \( P<0.1\% \)). The mean onset in group D was significantly above that in other groups combined (P<0.1%). Further evidence on the same theme was provided by the rising incidence of subjects with sensations which were confined to the fingers, a feature of less intense responses (Lewis and others, 1931; Zotterman, 1933; Weddell and Sinclair, 1947). Pricking-tingling distinctions were not stressed because of the difficulty of establishing differences independent of intensities, but these results favoured a general reduction rather than a selective impairment of either of these elements.

In sharp contrast to I.P., P.I.P. were usually diffusely referred to the hand, and though they might be first noticed patchily in median or ulnar nerve territories, the complete selective involvement of one territory was not seen. However, some preferential reference to areas on the radial or ulnar side of the hand was seen in 12 instances, 10 favouring the former and two the latter. The radial preference was noted in the younger groups.

Post-ischaemic Muscle Twitching.—Though observations were not made in all subjects and the assessments were crude, the incidence of distinct twitching was lower than for I.P. or P.I.P. (Table (b)). This finding was in keeping with the fact that sensory responses are more readily induced than motor (Kugelberg, 1944, 1946, 1948). Such twitching predominated in the young, where it appeared more severe (Table (b)).

Series II.—In this group of normal and near-normal subjects the incidence of occurrence of I.P. and "10-minute" P.I.P. showed the same decrease in response with age. In the usual four age groups A, B, C, and D, I.P. were clearly present in 93%, 77%, 59%, and 29% respectively (total subjects = 96). Post-ischaemic paraesthesiae were elicited in 65 subjects (10 in group D) with occlusions of 10 minutes or less, and were lacking in six subjects (four in group D) with occlusions of 10 minutes or longer. However, in four subjects (two in group D) the P.I.P. were only transient after 10-minute occlusions, so that, as with I.P., the proportion of subjects with little or no response was greater than in Series I. This appeared to be partly due to dull witnesses in Series II (which was under-represented in this respect), but there were other noteworthy features. Thus subjects with severe wasting from motor neurone disease formed the only two entirely lacking P.I.P. outside the oldest group (D), and the only good witness lacking clear I.P. in the youngest group (A); so that if these and poor witnesses were excluded, definite I.P. were invariably present in the young, and "10-minute" P.I.P. in all but a minority of the elderly as in Series I.

The general similarity of the results in both series suggested that factors of hypertension, anaemia, and cool limbs were not of great importance. Though the numbers were small, subjects with these "abnormalities" were considered separately to see if this was confirmed. Sixteen hypertensive and 13 anaemic (haemoglobin 55 to 74%) subjects showed results closely similar to those in Series I. Moreover, paraesthesiae were elicited with incomplete circulatory arrest as previously reported (Weddell and Sinclair, 1947; Merrington and Nathan, 1949), so that any minor leak could scarcely account for major defects. However, the responses in 16 subjects with cool limbs (cleft temperature < 78° F.) differed from those in Series I in showing an exaggeration of ageing trends. Thus I.P. were more frequently lacking in the older groups, and P.I.P. more prolonged in the younger than might be expected from results in Series I. Nevertheless this effect was not
marked since the results in 12 subjects who had had repeated tests on the same or opposite limb when warm and cool (interdigital cleft temperature differences 7 to 18°F.) revealed no great change. Repeated water-bath experiments in an experienced young subject with thorough warming and cooling of the limbs to extremes of 97°F. and 60°F. showed a slight diminution of I.P. in the cold tests with a prolongation of P.I.P. of up to 20%. Previous workers have reported either no change (Weddell and Sinclair, 1947) or effects of this type (Bazett and McGlone, 1931; Lewis and others, 1931; Merrington and Nathan, 1949). It thus appeared advisable to avoid wide temperature differences in comparative assessments, though the usual range of clinical variation seemed unlikely to disturb essential issues.

**P.I.P. in Occlusions Greater or Less than 10 Minutes.**—The responses after prolonged occlusions were not studied extensively in view of the danger in the elderly. Occlusions of seven to 32 minutes' duration in 35 subjects (ages 18 to 44 years) were compared with those of seven to 27 minutes' duration in 13 older subjects (age 48 to 64 years). This confirmed that P.I.P. were usually shorter lived in the older subjects.

**Constancy of Results.**—The constancy of paraesthesiae responses in experienced subjects has been previously established (Lewis and others, 1931; Weddell and Sinclair, 1947; Merrington and Nathan, 1949) and is entirely supported by present studies. Analysis of the results of repeated tests in the same or opposite limb of over 50 subjects in this and allied investigations (Poole, 1954) showed that the responses were essentially symmetrical and reproducible in inexperienced subjects. The few discrepancies as to the presence or absence of I.P. occurred only when these were very faint and where there was some complicating factor such as excessive discomfort, a poor witness, or a large temperature difference. Though individual variations in the actual time course of I.P., and to a lesser extent of P.I.P., occurred, the mean group responses for the initial and repeat tests were very similar. There was evidence of a slight "practice" effect, the mean onset of P.I.P. being reduced by <10% in a repeat series, and the mean duration prolonged similarly. Thus there were no grounds for doubting the validity of the broad details of isolated performances in paraesthesiae assessments. In lower limb occlusions Marshall (1952) found experienced and inexperienced subjects achieved the same test-retest consistency. It might be noted that the only instance of a marked right-left difference occurred in a young subject with hysterical symptoms who consistently denied all paraesthesiae in one limb, but nevertheless showed prominent post-ischaemic muscle twitching bilaterally.

**Relationship between Defects in I.P. and P.I.P.**—There appeared to be a simple connexion between I.P. and P.I.P. in that where I.P. were present P.I.P. followed, but where I.P. were lacking P.I.P. were usually of shorter duration than the group mean and might be entirely absent. This suggested that had the standard occlusion been shorter, P.I.P. might have been lacking as frequently as I.P. This association of defects in individual cases reflected the trends seen in the series as a whole, and suggested some common factor was responsible. It was noteworthy that, apart from the hysterical patient mentioned above, muscle twitching was never unequivocally present in the absence of P.I.P., suggesting a common reduction in iterative responses. From the practical viewpoint it was apparent that if I.P. were clearly present there was no need to continue the occlusion to ascertain if P.I.P. would follow. The occurrence of post-ischaemic muscle twitching in the absence of P.I.P. might also attract attention.

**Subjects Lacking I.P. and P.I.P.**—There was no clear difference between subjects with and without I.P. or P.I.P., and the latter were not inferior witnesses. Two subjects, one lacking and one with minimal I.P., undergoing repeated tests, noted sensations of burning and possibly tingling at sites of recent trauma during ischaemia as Nathan (1953) reported, thus showing their acuity as observers and the fact that impressions not unlike paraesthesiae could arise in appropriate circumstances.

An obvious possible factor to be considered was the long-established ageing change in vibration perception. However, this is not agreed in the upper limbs (Pearson, 1928; Gray, 1932; Laidlaw and Hamilton, 1937; Cosh, 1953), though since I.P. are relatively mild sensations slight changes might be relevant. No attempt was made to assess absolute vibratory thresholds as a routine, and in group D (Series I) there was with the usual clinical testing no clear suggestion of consistently better preserved acuity in subjects with I.P. However, in other studies (Poole, 1954) involving repeated estimations of vibration perception with a Symns tuning fork (Symns, 1912, 1917) in younger subjects, the thresholds were generally slightly higher in those lacking marked I.P.

**Discussion**

This study shows features of paraesthesiae sufficiently uniform for use as criteria of normality
in nervous disease (and disturbed ionic states) provided age is taken into account. Thus, though exceptions may occur, the absence of I.P. in the young and of "10-minute" P.I.P. in any except the elderly may readily attract attention. The influence of age provides a possible explanation for divergencies in previous reports as to the invariable occurrence of I.P. in upper arm occlusions (Weddell and Sinclair, 1947; Sinclair and Hinshaw, 1951; Cosh, 1953; Gilliatt and Wilson, 1953, 1954), and is in keeping with the occasional absence of paraesthesiae reported in the lower limb (Marshall, 1952) where ageing changes might be more marked. The lack of paraesthesiae despite any manifest sensory impairment is not surprising, since in any limb paraesthesiae are not referred uniformly to all surfaces of the hand. Factors determining this asymmetry (and the distal reference of paraesthesiae) are not established, but such results suggest that paraesthesiae assessments may provide a sensitive index of nerve function. This possibility is supported by other evidence such as the fact that after a period of limb ischaemia though sensation rapidly returns to normal (Lewis and others, 1931) paraesthesiae may not be elicited to their full extent again for many hours (Merrington and Nathan, 1949). Studies (to be reported) in polyneuritis, where distal innervation is also preferentially involved, confirm the sensitivity and possible value of such assessments as indices of affection.

The basis for the ageing changes is of importance to indicate the type of lesion when such defects occur in nervous disease, and also as a contribution to the study of ageing processes. The possibility that decreasing mental acuity was responsible must be considered, but is offset by the diffuseness and internal consistency of the changes, including also objective assessments of post-ischaemic muscle twitching. Decreased efficiency of limb compression by vascular or tissue sclerosis would not seem adequate explanation, since complete circulatory occlusion is not essential for the production of paraesthesiae. Moreover, associated observations on sensory impairment (Poole, 1954) showed that the induced sensory defects, rather than being delayed, were in some respects possibly earlier in onset in the elderly, though this might be due to the absence of I.P. allowing of uncomplicated assessment. However, fibrosis might act in a more subtle way such as by impairing ionic diffusions, e.g., K+ from ischaemic muscle. Changes with age in blood calcium (Carlson, 1952) or pH (Shock, 1952; Shock and Yienst, 1950) do not provide a satisfactory explanation. Lowered nerve temperature with age must be considered (Wagman and Lesse, 1952) but, though temperature effects may be complex, the paraesthesiae responses elicited from cool limbs and other evidence (Adrian, 1930; Katz, 1936; Hoff and Grant, 1944; Norris, Shock, and Wagman, 1953) do not favour this explanation.

The most likely origin for the changes would seem to lie in the peripheral nerves in three possibly interrelated fields: (a) reduction in fibre numbers; (b) alterations in fibre relationships from connective tissue infiltration with or without fibre degeneration; and (c) changes in nerve function without necessarily an obvious structural basis, such as in those properties determining the accommodation and relative repetitiveness of motor and sensory fibres (Skoglund, 1942; Granit and Skoglund, 1943; Kugelberg, 1944). In this last respect it is noteworthy that the essential feature of the ageing patterns is a change towards the motor type of response with a lesser tendency for repetitive discharges. It is not possible to discuss the many relevant ageing changes in nerve structure (Cottrell, 1940; Rexed, 1944; Corbin and Gardner, 1937; Gardner, 1940) and function (Green and Bender, 1953; Boman and Jalavisto, 1954; Petersen and Kugelberg, 1949; Laidlaw and Hamilton, 1937), but mention might be made of the progressive reduction in the maximum conduction velocity of ulnar nerve fibres with age (Wagman and Lesse, 1952; Norris and others, 1953) similar to the reduction in duration of P.I.P. This has been attributed to altered membrane properties rather than to fibre degeneration which has been considered insufficiently extensive. This raises the possibility that a change in iterative tendencies may precede functional (or structural) fibre disruption.

It is noteworthy that when a limb undergoes repeated occlusions over a short period, paraesthesiae are progressively reduced in a manner closely similar to ageing changes (Weddell and Sinclair, 1947; Merrington and Nathan, 1949). This might favour a chronic ischaemic aetiology and suggests some relationship with factors determining the heightened ischaemic susceptibility of motor and sensory functions after an ischaemic episode (Lewis and others, 1931; Barlow and Pochin, 1948) though this latter is not clearly evident in ageing. Another factor to be considered is myelin impoverishment since paraesthesiae are readily disturbed in polyneuritis. Clearly many changes may be primarily or secondarily responsible; further studies of factors determining the nervous discharges and of ageing changes in fibre characteristics may clarify this.
Conclusions

Ischaemic and post-ischaemic paraesthesiae decrease with ageing; certain features appear sufficiently constant to provide clinical criteria of normality provided age is taken into account.

Thanks are due to Dr. W. Ritchie Russell and Dr. C. W. M. Whitty for criticism of the text, and to N. M. Bailey, M.A., for statistical advice. The work was performed during the tenure of a Henry Goodger Scholarship.

REFERENCES


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REFERENCES


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