A similar inquiry was made into the long-term results of 100 children who had received injuries to the head during the years 1949 and 1950; this group was also consecutive.

TABLE IX

Type of Work	Average Period After Discharge Before Resuming Work
Return to normal work	10½ weeks
Return to light work and then normal work resumed	27 "
Remaining on light work up to date	32 "
Worked irregularly	16 "

The survey was carried out by means of a questionnaire to the parents; 82 replies were received.

Of these children, 51 were of school age when injured, 30 were below that age, and one child was already mentally retarded and unable to attend school.

Forty-three children were able to return to school in their pre-accident class and were able to compete with their age groups. In eight cases the educational standard was affected, the children either being returned to their original class but not moved up with their age group in the normal way or, immediately on return to school, being found to be below standard and placed in a lower class. In these eight cases it is judged that an intellectual injury of some degree has occurred which is likely to influence adversely the scholastic career of these children for the rest of their lives.

Fifty-two children were free from symptoms. Thirty complained of headache and/or dizziness. Fits were reported in four cases.

Changes in temperament were noticed in 27 instances, the main symptoms being nervousness, lack of concentration, faulty memory, bad temper, and bed-wetting, the parents stating in each instance that these manifestations had not been present before the injury.

Discussion

From the figures announced by the Ministry of Transport 5,250 people died during 1951 as the result of injuries received on the roads. So far as can be estimated, at least 60% succumbed as a direct result of injury to the head, and for every death four or five people receive non-fatal injuries.

This subject is important, not only because of the magnitude of these figures but because healthy people, not those already incapacitated by disease, lose their lives or are maimed. Indeed, the economic loss to the nation because of injuries to the head is enormous. Our figures, however, show that road carnage constitutes only 44% of the total number maimed or killed, the remainder being due to accidents in industry, in the mines, in the home, etc.

To meet the increasing needs of cerebral trauma, not only are further facilities for treatment and rehabilitation necessary but postgraduate schools at university level must soon be established for the instruction of those whose responsibility it will be to care for the head injured away from special centres. Whether such centres should be named "head injury" or "traumatic" is of little importance. A seven-day, 24-hour service is necessary, including facilities for radiology and for all other ancillary investigations. Here again we should like to call attention to the necessity for the closest co-operation between the neurological and the facio-maxillary surgeons in the treatment of head injuries.

The imperfect liaison between the hospital and the general practitioner has been, and still remains, a weak link in the problem of head injury. We believe that much advantage would accrue from visits by the general practitioners to patients in hospital during the acute stages of the injury, and this important postgraduate association should be fostered. Also, much waste of man-power could be avoided if, when the time comes for consideration of a patient's

return to work, a conference between the general practitioner and the specialist were held in the patient's home surroundings when every aspect of the case could be reviewed. In this way unnecessary hardships could be eliminated and extremes of judgment tempered.

Finally, our post-mortem studies have shown that in a considerable percentage of deaths the injuries received are of such magnitude that they must be irreversible from the moment of infliction. Therefore, again we should like to stress the importance of prevention in the solution of this problem, which should be constantly in the minds of the medical profession, the ruling bodies, and the general public. The chance of serious injury about the head to the individual remains far too high.

Summary

Between 1941 and 1951 2,000 cases of acute injury to the head were admitted to the General Hospital, Newcastle-upon-Tyne. The results of an analysis of 1,400 of these (1,000 adults and 400 children) are given. In the 1,000 adult cases there were 175 deaths, 87 of them due to road accidents; 38 of the deaths resulted from accidents in industry. Of the 175 patients admitted in a state of coma, 121 died. There were 28 cases of extradural haemorrhage with compression of the brain in which there was a latent interval of consciousness: one patient died before operation was possible; of the 27 operated on 17 survived and 10 died.

Of the 400 cases in childhood (up to the age of 12 years) 147 were due to road accidents and 149 to falling from a height: 34 of the children died, 20 of them having been admitted in a state of coma.

CLINICAL AND EXPERIMENTAL STUDY OF SEGMENTAL PAIN FROM THE SHOULDER

BY

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The pain from diseases of the shoulder such as supraspinatus tendinitis or capsulitis is always referred. Although radiation to the arm and hand has been recorded, the distribution of this referred pain has received scant attention in studies of this common group of diseases from orthopaedic sources, nor indeed has it often been mentioned. The importance of its recognition lies in the differentiation from other causes of referred pain into the upper limb, so that unnecessary mistakes in diagnosis can be avoided. Further, clinical and experimental studies of this sort may shed light on the problem of referred pain and on the segmental supply to the shoulder-joint and related structures.

The pain is diffuse and deep, and can be reproduced by experimental noxious stimuli in several ways: one is by injections of 6% saline into the deep structures around the joint. If carried out accurately this method correlates the structure of origin and the segmental reference arising therefrom. It also closely simulates the pain found in clinical cases. Kellgren (1949), in

an extensive review of this subject, advises that each investigator should become his own guinea-pig, because by this painful experience much can be learned, not the least being the difficulty of finding suitable expressions to describe it. In a series of such experiments carried out on myself, the deep pain had a "metallic" quality, but as this is clearly an ambiguous description, meaning nothing to anyone except to me, the simple term deep pain is adhered to. As its name implies, the pain is felt deep in and not on the skin, because it is due to noxious stimuli acting on the spinal segments. This causes a false localization of the pain through unknown phenomena occurring in the central nervous system. It has a maximum intensity proximally and fades peripherally. Patients have described it as "running down the bone and out through the fingers."

Kellgren (1938) showed that experimentally produced pain from interspinous ligaments was always a diffuse segmental pain if the stimulus was strong enough. This also holds for the short tendons and muscles of the shoulder, even though these structures are not centrally placed, as are the interspinous ligaments. I found that irritation of the supraspinatus tendon or muscle belly produced deep pain on the outer aspect of the arm, and sometimes in the forearm and thumb. After the initial injection, which always produced the diffuse segmental pain immediately, the pain could be reproduced hours later by moving the shoulder. On injection of the supraspinatus muscle belly a spot was found that produced a continuous band of reference along the length of the limb (Fig. 1). Local tenderness was also noticed. The segmental pattern of this false localization is discussed later.

Present Investigation

The clinical cases and the segmental pain they displayed are here described. During this study a special clinic was opened, so that the questioning and examination of the patients and the charting of the referred pain could be carried out leisurely, which, as every orthopaedic surgeon knows, cannot be done during the hubbub of a routine orthopaedic clinic. In 8 out of 26 patients with supraspinatus tendinitis the pain was referred to the outer aspect of the arm and lower part of the deltoid muscle in an area that reached to just above the elbow (Fig. 2). It was occasionally referred as two narrow bands, on the antero- and postero-lateral aspects of the arm (Fig. 3).

FIG. 1.—The spinal segmental distribution in several injections of 6% saline into the supraspinatus muscle and tendon. Oblique hatching indicates muscle; transverse hatching and stippling indicate tendon. The arrows show points of injection.

In 18 cases the pain radiated down the entire length of the antero-lateral aspect of the upper limb, terminating at the base of the thumb (Fig. 4). The thumb, forefinger, or middle finger was included either singly or together in many cases, with a distinct predominance in the radial fingers.

In 15 patients with spasm of the short rotator muscles associated with tendinitis or injury, and in whom the shoulder was partially stiff, the pain was widely referred to

FIG. 2

FIG. 3a

FIG. 3b

FIG. 2.—The average distribution of pain in eight cases of supraspinatus tendinitis. The dark area indicates maximum intensity. This corresponds to the fifth cervical segment. FIGS. 3a and 3b.—A variation in the reference of the pain in supraspinatus tendinitis, as antero- and postero-lateral bands.

the area of the deltoid muscle and outer aspect of the arm to terminate above the elbow (Fig. 5).

In 35 cases of "frozen" shoulder the pain radiated from the epaulette region into the arm, in many spiralling across the dorsal aspect of the forearm to reach the dorsum of the hand (Fig. 6). Occasionally the pain was referred along the antero-lateral aspect of the forearm to reach the palm (Fig. 7). One or all of the fingers were often included, and there was a distinct tendency for predominance in the middle, ring, and little fingers. In a few the pain was referred to the side of the neck and cheek or to the inner side of the arm and chest wall (Fig. 8). In six cases the pain was referred diffusely to the whole arm, but with accentuation in certain segments (Fig. 9). As was to be expected, a quantitative increase of the diffusion of the deep pain occurred in the more extensive lesions, and this will be discussed elsewhere.

Discussion

In other words, despite the diffuseness and difficulty of description and location of this pain, a distinct segmental pattern was displayed.

Head (1893, 1900) and Foerster (1933) depicted the fifth and sixth cervical dermatomes as occupying the antero-lateral aspects of the upper limb, extending to the base of the thumb. If it is assumed that the supraspinatus muscle and tendon are supplied by the fifth and sixth cervical segments through the supraclavicular nerve, then in disease of these and related structures it is probable that the referred pain will appear to be blended and shared in varying degree between them. This is because of the close association of the two spinal segments in the formation of their nerve supply. In any case, the pain may not involve the whole segment of reference (Hilton, 1950). This is borne out by experimentally produced deep pain in the instance of this tendon. Anatomical variations, such as pre- and post-fixation of the brachial plexus and the segmental preponder-

FIG. 4.—The distribution of pain in 18 cases of supraspinatus tendinitis. The fifth and sixth cervical segments are probably involved. The numerals indicate a preponderance of pain in the digits on the radial side of the hand.

ance in the formation of peripheral nerves, must have a considerable influence on the distribution and fluctuation of referred pain in the upper limb, and probably accounts for the surprisingly high or low segmental reference in some cases of shoulder disease. Kellgren (1939) has shown the significance of anatomical variations in the instance of the

FIG. 5

FIG. 6

FIG. 5.—The average distribution of referred pain in 15 cases of spasm of the rotator cuff muscles. There is a broad band of reference in the fifth cervical segment, and perhaps even wider. FIG. 6.—The average distribution of referred pain in 35 cases of "frozen" shoulder. The numerals indicate a preponderance of pain in the digits on the ulnar side of the hand. The fifth to the eighth cervical segments are represented.

FIG. 7

FIG. 8

FIG. 7.—The distribution of pain in "frozen" shoulder when it radiates to the palm. FIG. 8.—This diagram indicates the wide areas of reference possible in lesions of the shoulder (see text).

lumbar spinal roots. The segmental impression of deep pain from the supraspinatus tendon and related structures corresponds to the dermatome chart of Last (1949) and closely approximates to the segmental distributions of Kellgren (1938) in many injection experiments.

The fifth and sixth cervical segments are usually said to supply the shoulder-joint itself (*Gray's Anatomy*, 1949). In "frozen" shoulder, however, as has been shown, the segmental reference may extend from the fifth to the eighth cervical segments, and sometimes more. The occasional higher or lower reference may be tentatively explained by the anatomical variations mentioned above, or there may be a central spread in the spinal cord, on the basis of the wide intersegmental synapses in the tract of Lissauer, as postu-

lated by Earle (1952). This distribution closely follows the dermatome chart of Last (1949) and the spinal segmental patterns of Kellgren (1938) formed by experimentally produced pain from the interspinous ligaments. It does not conform to the "strip" pattern, so popular nowadays, to be found in papers by Keegan and Garrett (1948), Young, (1949) and Walshe (1952), nor indeed to the map in Lewis's (1942) book, in which the dermatome of the eighth cervical segment occupies territory on the inner side of the arm. It is to be clearly understood that the pain is not actually in the anatomical entity known as a "dermatome," which is an area of skin, but, all the same, diffuse and deep as it is, the central misinterpretation of its distribution is that given above.

These latter conceptions ignore the axial lines. This applies particularly to the dermatome of the eighth cervical segment, which is usually the lower border of the segmental reference. Since all, or mainly the ulnar, fingers were included in referred pain from "frozen" shoulder it does seem that the eighth cervical segment was usually the lowest to be stimulated (Fig. 6). Thus when the capsule of the shoulder-joint was widely irritated and was the source of the noxious stimuli, the pain was falsely located in the territory between and cephalic to the axial lines. Further, Last (1949) and Hilton (1950) suggest that the segmental and the nerve supply of the muscles are the same as those of the joint they move, so, according to this reasoning and from the evidence deduced above, the segmental supply to the shoulder must span the fifth to the eighth cervical segments at least, without allowing for any anatomical variations. This is supported by the charts depicted in *Gray's Anatomy* (1949), but awaits definite anatomical proof.

The explanation of diffuse pain in the "whole" arm is bound up with the mystery of referred pain, and it is not my intention to become involved in this paper in a discussion of the various hypotheses on this abstruse subject, or to discuss the peripheral or central mechanism that may be involved. Those interested will find recent conceptions in Sinclair, Weddell, and Feindel (1948), and Hardy, Wolff, and Goodell (1952). But it is extremely unlikely, as is so often suggested by writers on physical medicine, that the entire brachial plexus becomes "sensitive" in acute lesions of the shoulder, to account for the widespread reference of the pain. It is much more likely to have a neuro-anatomical basis from phenomena occurring within the central nervous system.

Summary

Pain from lesions of the shoulder is usually a referred deep pain. Experimentally produced referred pain from the shoulder closely simulates that found in disease.

The referred pain from various lesions of the shoulder, although diffuse, displays a distinct segmental distribution.

It is suggested that this furnishes evidence to support the opinion that the fifth to the eighth cervical segments supply the shoulder.

FIG. 9a

FIG. 9b

FIGS. 9a and 9b.—The distribution of pain in the whole arm in six cases of frozen shoulder. The dark shading indicates accentuation in certain segments.

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FURTHER OBSERVATIONS ON THE METABOLIC STIMULATING EFFECT OF SALICYLATE

BY

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It has been shown (Cochran, 1952) that salicylate causes a pronounced and progressive increase in oxygen consumption when given in full therapeutic dosage to normal and subacute rheumatic subjects. It was suggested that this effect of salicylate might be of fundamental importance in the therapeutic action of the drug. The present paper is a continuation of this work and concerns two further aspects. Firstly, is seemed possible that salicylate might behave in an anomalous fashion in the acutely ill febrile patient, and therefore the effect of the drug on oxygen consumption in the treatment of acute rheumatic fever has been studied. Secondly, it is well known that salicylate (*ortho*-hydroxybenzoate) is effective in the cure of acute rheumatic manifestations, while its isomers (*para*- and *meta*-hydroxybenzoate) are inactive. The effect of these isomers on oxygen consumption has been studied.

Method

Oxygen consumption was measured, using a closed-circuit type spirometer, and the values obtained were corrected

for temperature and barometric pressure. The rheumatic fever patients had three consecutive five-minute tracings taken each morning at a constant time and the results were averaged. This routine was continued throughout the course of treatment. When it was desired to test the effect of a single dose of a drug each subject acted as his own control and was in the fasting state. After two or three consecutive tracings a single dose of the test drug was given by mouth and serial estimations of oxygen consumption were made at roughly 20-minute intervals for two to three hours.

Results

Observations were made on three patients admitted with acute rheumatic fever who received aspirin in full therapeutic doses of approximately 2 g. four-hourly. In each case the expected clinical improvement with relief of arthritis and fall in temperature occurred within 24 to 48 hours of starting treatment. In Figs. 1 to 3 the daily levels of oxygen consumption are plotted with the oral temperature obtained just prior to the oxygen measurement. In Fig. 1 it is seen that although the temperature has fallen by 4.8° F. (2.7° C.) the level of oxygen consumption has actually increased. When aspirin is gradually withdrawn the metabolic rate slowly falls. In Fig. 2 the temperature has fallen by 4° F. (2.2° C.), but the metabolic rate remains at an elevated level until an abrupt fall occurs when aspirin is suddenly withdrawn. In Fig. 3 there is a similar pattern of changes. The abrupt fall in temperature is accompanied by a progressive rise in oxygen consumption, which again falls only when aspirin treatment is stopped.

A fourth patient was treated at first with sodium salicylate and sodium bicarbonate in equal doses of 20 gr. (1.3 g.) four-hourly. The initial clinical response was satisfactory, but on reducing the dosage a relapse occurred and treatment was changed to aspirin. A second relapse followed aspirin withdrawal, and a further course was given. The relationship of relapse to oxygen consumption is shown in Fig. 4. It is seen that recrudescence of symptoms occurred when the oxygen consumption had fallen to low levels, either in reduction of dosage or withdrawal of salicylate.

A comparison was made of the effects on oxygen consumption of single 3-g. doses of sodium salicylate and aspirin and single 5-g. dosage of the *para*- and *meta*-hydroxy isomers of salicylate. The tests were carried out on the same convalescent patient, and the results are shown in the Table. Sodium salicylate and aspirin caused respectively a 12% and 11% maximal increase in oxygen consumption, while the two isomers were without significant effect. Two convalescent patients were given the isomers over a four-day period in doses of approximately 2 g.

FIG. 1

FIG. 2

FIG. 3

FIG. 1.—Effect of aspirin on oxygen consumption and body temperature in a patient with acute rheumatic fever. Although the temperature has fallen by 4.8° F. (2.7° C.) the level of oxygen consumption has increased and slowly falls when aspirin is gradually withdrawn. FIG. 2.—Results obtained in a second patient with rheumatic fever. The temperature has fallen by 4° F. (2.2° C.), but the metabolic rate remains at an elevated level until an abrupt fall occurs when aspirin is suddenly withdrawn. FIG. 3.—Results obtained in a third patient with acute rheumatic fever. An abrupt fall in temperature is accompanied by a progressive rise in oxygen consumption, which falls only when aspirin treatment is stopped.