UNIVERSITY OF GLASGOW

INTELLECTUAL CHANGES FOLLOWING PENETRATING BRAIN WOUNDS.

By

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A Thesis

submitted for the Degree of Doctor of Medicine

PREFACE

Early in the last war St. Hugh's College, Oxford, was converted into a hospital for the treatment of Army personnel suffering from head injuries; since 1946 its work has continued at the Military Hospital, Wheatley.

To begin with, the Military Hospital for Head Injuries dealt mainly with closed head injuries due to road accidents, but with the invasion of France in 1944 an increasing number of men suffering from high velocity missile wounds of the skull and brain were admitted. The majority of these men, of whom there were some 900, made an adequate recovery and returned to their homes. During the past two years this series of cases has been added to by the return of brain-injured personnel from Korea.

It was realised that the subsequent progress of these men, the study of their injuries, and the effect such injuries might have on their physical and mental capacities would provide an exceptional opportunity for investigating brain function. In addition, it was foreseen that in the years following the war these men would be faced with difficulties and problems for which they would require further help. Consequently, since that time an organization has existed in Oxford to which these men might refer for assistance (Russell, 1951). This consists of a small Head Injury Advice Bureau attached to the Military Hospital for Head Injuries, and a Rehabilitation Centre, run by the Joint Organisation of the Red Cross and Order of St. John, situated

at Headington Hill Hall, Oxford; to this Centre cases for review can be admitted for in-patient supervision and study. This organisation is under the direction of Dr. W. Ritchie Russell, C.B.E., in his joint capacity as Consultant Neurologist to the Army and to the Ministry of Pensions.

I joined this organisation in October, 1951, with a Beit Memorial Research Fellowship, to examine psychological changes in those men who had sustained wounds penetrating the brain. Part of my enquiry has been directed towards studying alterations in intellectual functioning as determined by intelligence tests, and this thesis describes the method of investigation used, its standardisation, and the results of its application in 70 cases.

It is with gratitude that I acknowledge the assistance received from Dr. Ritchie Russell in extending to me the full facilities of his Department. I am also indebted to him for much encouragement and guidance.

I wish to thank the Officer Commanding the Military Hospital for Head Injuires, Wheatley, and his staff for facilities received in that hospital; and Mr. Walpole Lewin, F.R.C.S., Consultant Neurosurgeon, for permitting me to examine cases under his care. I am indebted to the Army Medical Department and the Directorate of Man-power Planning, the War Office, for permitting access to pre-wounding mental test results and to the confidential Dominoes Test.

Finally, I should like to pay a tribute to the excell-

ence of the case records contributed to by the many who worked at the Military Hospital for Head Injuries and in the field during the late war, and to the American neurosurgeons responsible for the treatment of the Korean cases upon whose notes I have freely drawn.

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I. INTRODUCTION

Historical.

With the demonstration of the excitability of the motor cortex by Fritsch and Hitzig in 1870, and the prior assignment of speech faculty to the posterior end of the third frontal convolution by Broca in 1861, it was inevitable that further attempts should follow to define separate localisation of function within the cerebral hemispheres. From the investigation of the more obvious sensori-motor responses elicitable from the parts adjacent to the central sulcus, it was but a step to seek, within the cortical area, other parts where specifically mental functions would be represented.

Hitzig was not long in directing his experimental skill to the study of these higher functions, and eventually concluded that abstract thinking (das abstracte Denken) was dependent upon the frontal part of the brain. "According to Munk", he wrote (1884), "there are no special organs for these (higher intellectual functions), nor are they necessary. I certainly agree with him that intelligence - or, better, the store of ideas - is to be sought for in all parts of the cortex - or, better again, in all parts of the brain. But I maintain that abstract thought requires special organs, and I seek these provisionally in the frontal brain."

The significance of the frontal lobes as organs mediating higher intellectual functions was echoed by Ferrier (1886)

and Bianchi (1922). Ferrier, while believing that the frontal lobes formed the basis of those psychical processes which lay at the foundation of higher intellectual operations, nevertheless thought it absurd to speak of a special seat of intelligence in the brain. Bianchi, however, reasoning from the psychic disintegration which, in his experimental animals, followed the bilateral destruction of the frontal lobes, saw in them a cerebral organ which "had the faculty of utilizing the mental products of the sensory areas of the cortex for the construction of mental syntheses, an organ giving rise to reactions upon the world which, on the basis of individual and collective experience, permit a higher adaptation of the individual to his psychical and social environment, an organ which renders possible the unfolding of a long process of logically connected thought."

From these early experiments, based upon the simple observation of the behaviour of the animal after induced injury, there was growing the idea that there were areas in the brain where, to paraphrase the words used by Hughlings Jackson (1873) in regard to the localisation of movement, intelligence was "most represented"; and those areas were in the frontal lobes. Not all investigators of this time, however, were so convinced.

Goltz (1881), in his experiments with dogs, showed that the greater the amount of cerebral tissue removed, the greater was the resulting dementia. His measure of the

deficit was the amount of attention to stimuli shown by the animal after injury and the degree of failure in this respect indicated the degree of loss of integration and consequently of intelligent behaviour. If anything, the animal was less "intelligent" after removal of the posterior quadrants of the brain, and this was presumably so because of their greater mass.

If a constant relation could be established between the amount of brain tissue destroyed and the resulting dementia, then this would indicate that intelligence was dependent upon an inherent property of the cerebral substance which was equally distributed throughout the brain or, at least, throughout the cortex, the quantitative loss of tissue determining the quantitative loss of intellectual function.

Munk (1890), on the other hand, regarded intelligence less as an innate property of the cerebral substance, but rather as the resultant of a group of discrete cerebral activities; it was the summation of the separate functioning of specific sensory fields. This view was in essence the same as that of Ferrier when he said: "There are centres for special forms of sensation and ideation, and centres for special motor activities and acquisitions, in response to and in association with the activity of the sensory centres; and in these in their respective cohesions, actions and inter-actions form the substrata of mental operations in all their aspects and all their range."

It can be seen, therefore, that three principal trains of thought were developing on the part played by the brain in the psychic life: (a) Intelligence was mental activity whose physical basis was more or less strictly localised in the brain and in the main the frontal lobes were the place of choice. (b) Intelligence was a property of nervous substance, a function of the whole brain, destruction of part of which would lead to a corresponding diminution in intelligent behaviour. (c) Intelligence was the result of the integrated activity of certain sensory and motor fields.

These experimentalists, however, variously interpreted the nature of the function which they each described as intelligence: to Hitzig it was abstract thought; to Goltz the ability to attend to extraneous stimuli; and to Munk and Ferrier a sort of sensory epiphenomenon.

Modern Developments.

Since the beginning of the century several factors have enhanced our understanding of the nature of nervous organisation in intelligent behaviour. In the field of animal psychology experimental methods, using the latch-box and maze, originally devised by Thorndike (1911) to study learning in the brain-intact animal, were adapted, notably by Franz (1907) and Lashley (1929), to investigate the effects of cerebral excision on the ability of the animal to learn or to reproduce previously learned behaviour.

Developments in neurosurgery, the aftermath of two wars, and the introduction of cerebral surgery as a treatment for mental disease (Moniz, 1936), have all made human material available for study; while a scientific assessment of intellectual deficit after brain injury in man has become possible since the first objective tests to measure intelligence were designed by Binet and Simon in 1905.

In animal research the outstanding contribution has been that of Lashley which he has recently summarised (1950). His work has many facets, but the one which mainly concerns us here is that dealing with the effect of cerebral injury on the formation and retention of the complex maze habit in the rat. Lashley used rats because they were readily obtainable in large numbers and so his results could be given statistical validity. He demonstrated that rats trained in the maze completely lost the habit if more than 50% of the cortex were removed and that re-learning required as many times as much practice as did initial learning. His evidence also indicated that the more difficult the task the greater was the relative effect of larger lesions. He obtained similar results, also in the rat, in experiments using the latch-box. No matter what part of the cerebral hemispheres was destroyed, the amount of loss of habit from a given extent of cortical destruction was about the same, provided the destruction was roughly similar in both hemispheres. Although loss of sensory cues due to the invasion

of various sensory fields by the lesion played a part in the habit deterioration, it could not account for all of it; while destruction of the primary visual cortex in blind animals trained in the maze produced a severe loss of the habit with serious difficulty in re-learning, although the animals could have used no visual cues during the initial learning.

Similar results have been obtained from studies of the associative areas in the monkey. Visual and tactile habits were not disturbed by the destruction, singly, either of the occipital, parietal, or lateral temporal regions, so long as the primary sensory fields remained. Combined destruction of these regions, however, produced a loss of the habits with retarded re-learning. Higher level activities, such as the conditional reaction, delayed reaction, or the solution of the multiple stick problem, showed deterioration after extensive damage in any part of the cortex. The capacity for delayed reaction (e.g., to remember in which of two boxes food was placed) was seriously reduced or abolished by removal either of the prefrontal lobes or of the occipital associative area or of the temporal lobes. Small lesions, therefore, embracing no more than a single associative area, did not produce loss of any habit; large lesions produced deterioration which affected a variety of habits, irrespective of the sensori-motor elements involved.

In man, clinical studies on the effect of brain injury in producing intellectual deficit have resulted in the accumulation of a considerable amount of evidence, much of it contradictory. The absence of consistently gross functional disturbance after removal has made the prefrontal areas suitable for extensive excision, while their association with emotional reactions makes them the centre of attack in the surgical treatment of psychological illnesses. Consequently, most of the studies have been concerned with the frontal lobes. Some of these must now be considered briefly.

Men with injuries sustained in the 1914-18 war were examined by Kleist (1934) and Goldstein (1942). Kleist carried out a major investigation into the results of injury to different parts of the brain, but did not use objective tests in assessing intelligence; he came to the conclusion, however, that intellectual losses were associated mainly with lesions of the supero-lateral aspect of the frontal lobes.

While Kleist's approach tended towards extreme localisation of function, Goldstein's was just the opposite. In lesions of the frontal lobes, of other parts of the brain, and those causing amnesic aphasia, there was a common defect, as shown by the patient's natural performance and by specially devised tests; this defect was loss of the ability to abstract with good retention of concrete behaviour. There was a consistent difficulty in shifting from one aspect of

a performance to another, in making a choice or finding the essentials of a situation; "a characterisation", according to Lashley (1950), "too vague and general to give a picture of the functional disturbance."

The effect of massive removals of brain tissue has been studied by Rowe (1937), Jefferson (1937), Rylander (1939) and Hebb and Penfield (1940), among others. Rowe describes a case in which complete removal of the non-dominant hemisphere for brain tumour resulted in no loss on tests of the Binet-Simon type after operation as compared with before. Unfortunately he does not give details of the testing. Jefferson's study was purely clinical and he used no objective tests, but no obvious intellectual deficit was apparent after removal of either the right or left frontal lobe. Rylander's careful investigation of 32 cases of frontal lobotomy, using a matched control group from the normal population, showed, on the other hand, significant losses on intelligence test scores; while Hebb and Penfield describe a case in which the anterior one-third of the frontal lobe was removed bilaterally in a man suffering from post-traumatic epilepsy; his post-operative scores, mainly on tests of the Binet-Simon type, were consistently higher than those obtained pre-operatively.

Studies of intellectual functioning following the operation of pre-frontal leucotomy have shown similar variable results. Malmo (1948), and Petrie (1952), report a fall in scores, while Carscallan (1951) and his associates

found, in cases of chronic schizophrenia, that such scores rose above the pre-operative level. Where, instead of cutting the deep white fibres as in leucotomy, selective partial ablation of the frontal cortex has been performed (King, 1949), then no significant differences were observed.

A recent well-designed study (Struckett, 1953) deserves detailed consideration. In this investigation 26 male patients suffering from chronic schizophrenia were used and were tested pre-operatively as well as after standard pre-frontal leucotomy at intervals of 3 weeks, 3 months, 6 months and 1 year. In addition, pre-morbid test scores (i.e., scores obtained before the onset of the schizophrenic illness) were available from Army sources in 11 of the cases. The most important finding was the significance of the time factor in testing intervals. Three weeks after operation a decrease in intellectual functioning was apparent, but it was followed by a gradual increase, until by the six-month period the intellectual functioning equalled or surpassed the pre-operative level. Further increases in intellectual functioning were demonstrated at the one-year period. Impairment in these psychotic patients was exhibited compared with their pre-morbid level, but after operation the scores tended to approach it once more. Struckett concluded that "after six months no adverse effects on intellectual functioning were demonstrated by the objective psychometric measures utilized in this study."

It is apparent that the use of conventional tests to estimate intellectual deficit after different degrees of cerebral (particularly frontal lobe) destruction has produced uncertain and often ambiguous results. Halstead (1947) has applied a large battery of tests (mostly self-designed), of doubtful validity and doubtfully controlled, to a series of 50 cases of frontal lobectomy and considers that injury to the frontal lobes gives rise to defects in "biological intelligence", a concept of his own which he nowhere defines.

The difficult problem of intellectual change after cerebral injury will not be the more readily resolved by disguising it in a new language. Intelligence may not be easy to define, but intelligence tests are measures of a sort of mental function, the nature of which is generally understood by psychologists and other workers in the field. It is important, therefore, that we should continue to use, in cases of brain damage, standard psychometric tests which have been adequately validated on large numbers of normal people.

Intelligence and Intelligence Tests.

Intelligence is an innate capacity, varying quantitatively from person to person, concerned with the development of intellectual skills, with the solution of practical problems, and with insight into complex situations. It is not acquired experience, but is a means by which such

experience is built up, integrated, and understood. It is a mental function which enters into everyday, as well as into high-grade intellectual, tasks.

Whatever intelligence may be in practical life, intelligence theory has based its concepts upon intellectual performance as revealed by intelligence tests. On the whole these tests have proved accurate predictors of success in activities requiring intellectual ability, however remote these activities might be from the actual test situation. "It is incontestable", says Bartlett (1947), "that the application of the tests has made it possible to predict successfully, in a statistical sense, certain forms of success which are widely valued in present-day society." It is therefore a valid assumption that such tests are assessing a mental function which bears at least a close relation to what might be termed "natural" intelligence.

The original tests devised by Binet and Simon were designed to differentiate degrees of intellectual capacity in school-children. This they did by sampling the child's performance in various sorts of ability (verbal, calculating, space perception, memory, relational thinking) and by seeing how far the performance exceeded or fell below the expected average for the child's chronological age. Although these tests worked remarkably well and are still widely used in modifications such as the Stanford-Binet (Terman and Merrill, 1937), it is now recognised that they depend too

much upon mechanical remembering and not enough on the ability to solve problems set in a novel situation. Tests of this kind which depend to a large extent upon the reproduction of acquired experience - which may well be mostly preserved - will be inadequate instruments by which to judge the ability of the patient to solve new problems after brain injury.

It is impossible, however, to avoid some degree of experiential sophistication in the construction of an intelligence test. A test is set in a medium consisting of symbols of a verbal, numerical or visual-spatial type; such symbols are learned and are thus the product of experience. A modern intelligence test, however, is not merely one of symbolic recognition, but one which involves a new element in the "thinking-out" of a problem. It is therefore an essay in "problem-solving" set in a symbolic medium and involving tasks of increasing degrees of complexity.

Most of the present controversy on the structure of intelligence centres round the nature of the factors involved in this problem-solving activity. This controversy can be stated simply as follows: Is intelligence composed of a number of independent intellectual factors one or more of which may come into operation in any specific mental task, or is there a general factor which enters into every mental task irrespective of the field in which the task is set?

It was Carl Spearman (1904) who first postulated a central or general factor in intelligence. This factor, called g (general potentiality), he eventually identified largely with the ability to see and use relationships. "Everything intellectual can be reduced to some special case or other of educing either relations or correlates." (Spearman, 1923)

Spearman's approach was essentially mathematical, and it was by this means that he was concerned to study the relation between one ability and another. He realised that individual abilities were always positively correlated with each other, although the correlation might be high or low. The exact statistical method which he used to make the raw correlations reliable indices of association need not concern us here; it is sufficient to say that the degree of correlation between various types of test could be accounted for by a single factor common to them all, and this factor was g. Only memory tests did not fulfil his criteria, and he concluded that retentivity was an entirely different process from intellection. In the solution of the intellectual tasks involved in the tests two factors were at work: a general factor, g, and a special factor, s, the latter varying with the specific ability being tested.

The "two-factor" theory of intelligence has by no means gained universal acceptance, and has been criticised by Thomson (1916) in this country and by Thurstone (1935)

in America. Thurstone has attempted to define certain "primary mental abilities". These primary abilities or factors (inductive, deductive, memory, spatial, number, word, perceptual) are autonomous, although - again with the exception of memory - they all correlate highly with one another. This suggests little more than a re-statement of g, a fact which gives some point to the view (Vernon, 1950) that it is both "psychologically foolish and mathematically difficult to belittle g."

However intricate a function intelligence may be, there can be no doubt that relating activity is one of its most fundamental attributes, and as Hearnshaw (1951) has noted "test constructors have tacitly accepted the theory that intelligence consists of the grasping of relationships." Such relating activity is by no means a human prerogative, and the power to effect relevant generalisation by a process of abstraction, so that objects can be classed as having a common property, is characteristic of much simpler nervous systems than our own. Indeed, Lashley (quoted by Adrian, 1947) regards generalisation as one of the primitive basic functions of organised nervous tissue:

> "For example, transposition of reactions has been found in all organisms capable of a differential response. That is, when an animal is trained to choose the larger or brighter of two objects and is then confronted with a still larger or brighter he chooses on the basis of relative size or brightness. Such generalisations are universal from the insects to primates."

An intelligence test is a test of relating activity.

Such activity, however, can vary from the simple abstraction of the common elements in a field occurring at little more than the perceptual level to what Hearnshaw (1951) has termed the "ordering of manifold and heterogeneous experience through the grasp of abstract principles of order". Complex processes of conceptualisation, upon which the development of all the higher symbolic activities of man are based, are not more than incidentally touched upon in the average intelligence test. Moreover, as Bartlett (1947) has pointed out, "practically all known intelligence tests lead to bunching at the top end, so that alleged differences between the more highly intelligent, based upon test performance, have very little importance." Nevertheless, however imperfect an intelligence test may be in assessing the more complicated aspects of human mental functioning, it represents a standardised measure of a sort of mental performance and as such can be used to provide an estimate of the integrity or disintegration of that type of performance after brain injury.

Problems studied in this Thesis.

In this thesis the results are described of the application of a group of problem-solving tests to 70 cases of penetrating brain wounds, in all cerebral sites and of all degrees of severity. Three tests have been used: one verbal-numerical (Hartford Retreat Test), one largely visual-spatial (Raven's 1938 Progressive Matrices), and

one numerical-visual-spatial (Dominoes Test), each being concerned with the apprehension of a series of relations which increase in complexity throughout the test. It has been assumed, therefore, that, where the subject fails to perform on these tests at his expected level with regard to his pre-injury intelligence, such failure is due to his inability to see through the more complex relations. The main problem studied in this thesis, therefore, has been to find out what kinds of injury produce a loss in this relating activity.

Now it is recognised that failure to perform adequately on a particular test may not be due to a failure in this relational function at all but is rather the result of a selective breakdown, due to the injury, in the appreciation of the particular symbolism used in the construction of the test. Thus, the breakdown of verbal symbolism in dysphasia/dyslexia, may mean that the subject will do badly on a test such as the Hartford Retreat Test because he can no longer deal effectively with the verbal symbolism involved. Similarly, a patient with topographical disorientation following a parietal lesion (Patterson & Zangwill, 1944, 1945) may find it difficult to deal with the visual-spatial patterns of the Raven's Matrices. In the cases described in this thesis, therefore, no unequivocal loss in relational function has been assumed unless there has been good evidence of intact symbolic appreciation and unless the subject's failure has occurred at approximately the same level on

each problem-solving test used. In this material the commonest symbolic disturbance has been verbal, and cases with clinical evidence of dysphasia have been dealt with as a separate group.

METHOD OF INVESTIGATION

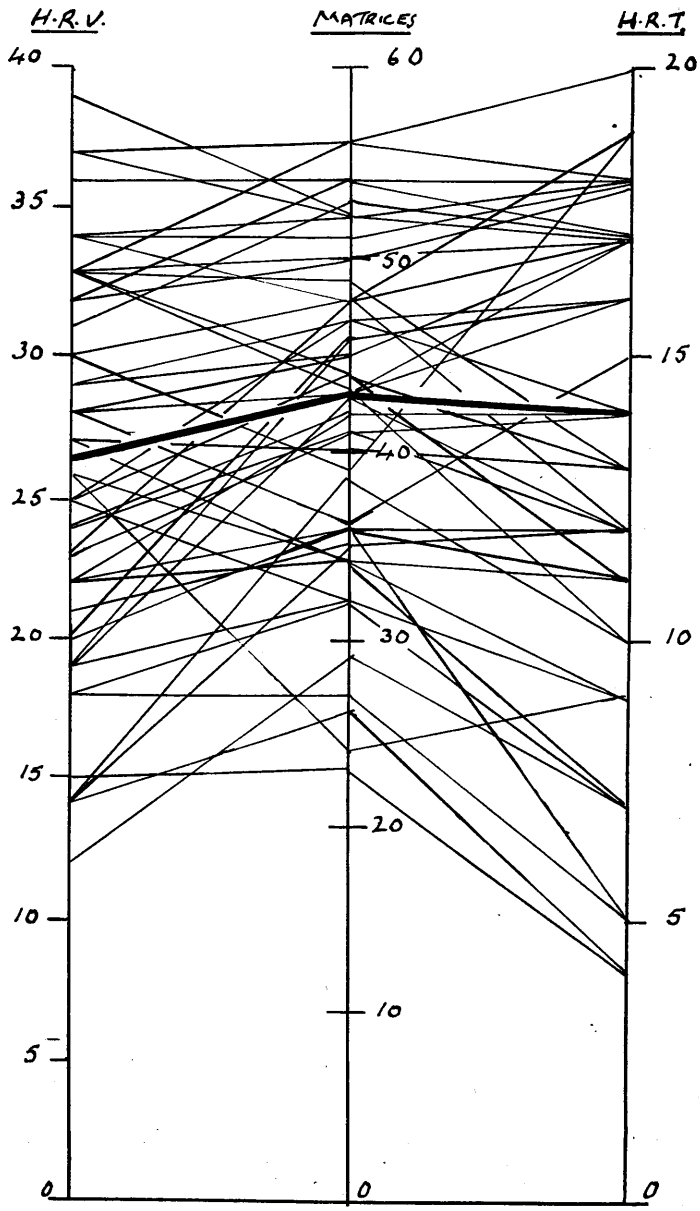
Most methods devised to demonstrate intellectual impairment in organic cases are based upon groups of tests, some of which show respectively some resistance or vulnerability to trauma. Thus, when a patient after brain injury is not dysphasic, his ability to reproduce vocabulary is usually preserved, and this can be used as an indication of his pre-traumatic intelligence level, because it is generally true that the higher an individual's vocabulary (i.e., the greater the number of words he knows) the higher is his general intelligence.

The method now described has been based on this principle. The tests used are all well known, but they have been re-standardised for the purpose of this investigation against a group of normal controls. They are the 1938 Raven Progressive Matrices, the Hartford Retreat Vocabulary (H.R.V.) and the Hartford Retreat Test (H.R.T.). These tests have been administered to the normal controls to estimate what levels of vocabulary on the H.R.V. are equivalent to what point scores on the Matrices and on the H.R.T., the maximum score on each being: H.R.V., 40; on the Matrices, 60; and the H.R.T., 20.

Control Tests.

The controls used were 50 Servicemen aged 18 to 35 (median age 19) who were thus in approximately the same age-group as the men who had sustained

Figure 1.


H.R.V.
MATRICES
H.R.T.
40
35
30
25
20
15
10
5
0
60
50
40
30
20
10
0
20
15
10
5
0

the penetrating brain wounds. They were a sample of men admitted to the general wards of the Military Hospital for Head Injuries, suffering from medical and surgical conditions, the only criterion in their selection being that cases with brain damage and psychoneurosis were excluded. The rank, age, unit, service, trade, civilian occupation, and the results of mental testing, in each case, are given in Appendix A.

In addition the results of testing have been plotted on Figure 1, and the median score on each test for the whole group has been superimposed as a thick line. The median score on the Matrices in the controls is 43, while Raven's median score for this age-group is 44, calculated from the natural scores of several thousand soldiers and civilians (Raven, 1950). This indicates that the control group is a representative sample of the normal population of this age-group. In this control group, therefore, the median score on the Matrices is 43, in the H.R.V. 26.5, and in the H.R.T. 14.

The distribution of the results in these 50 normal controls shown on the diagram demonstrates a wide scatter between the ability to reproduce vocabulary and to perform problem-solving tests, especially in the lower and medium intelligence levels. It can be seen, however, that when the higher vocabulary levels are reached the results on the Matrices and H.R.T. tend to equate more consistently with

the vocabulary scores, as shown by the greater number of lines going almost straight across. In using a method such as this, therefore, to estimate the presence or otherwise of intellectual impairment, it is necessary to avoid drawing conclusions which are not justified in view of the range of the normal sample.

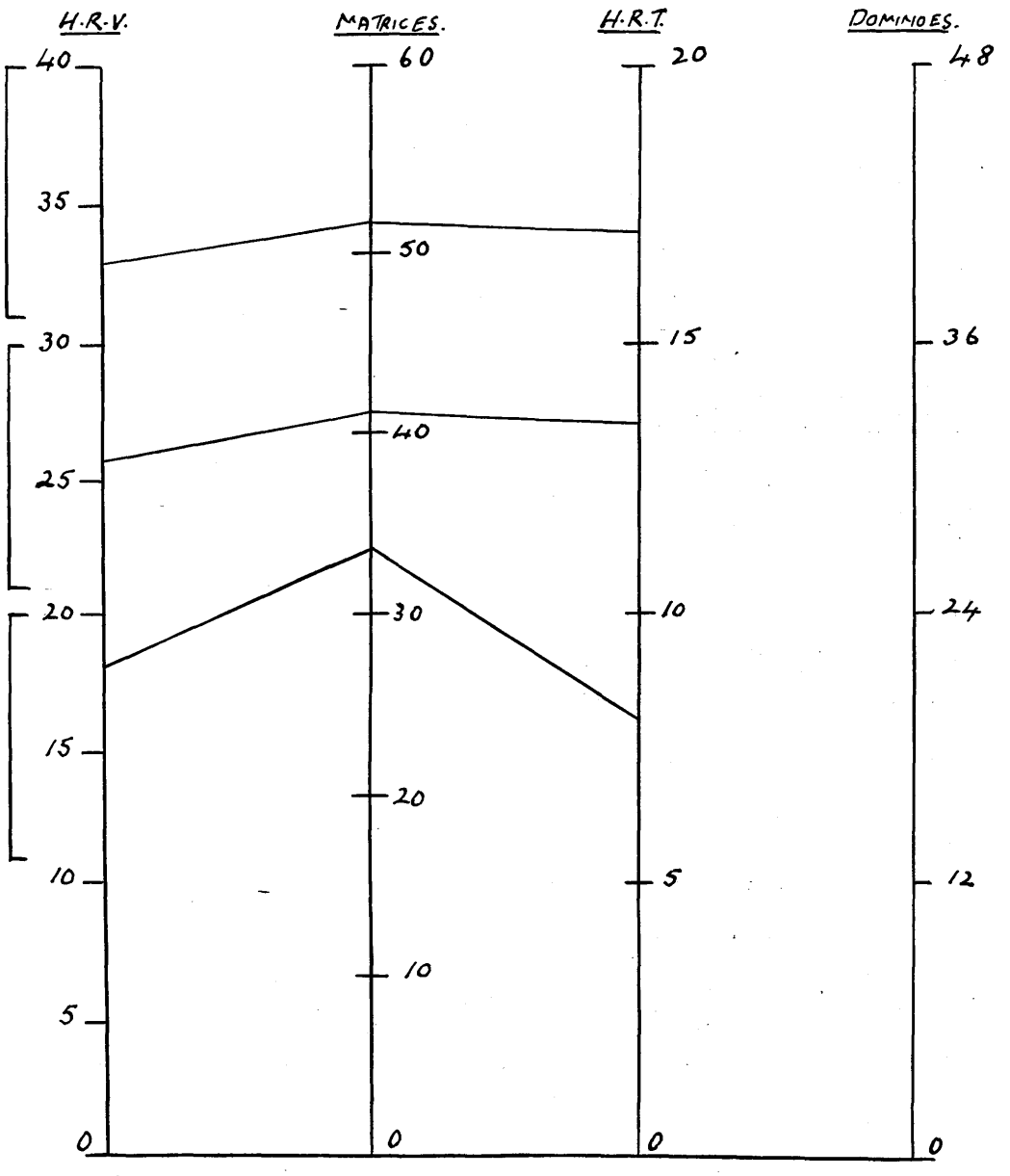
Test Results before and in the Early Stages of Injury.

The injured men who were enlisted in the Army from 1942 to 1948 were given intelligence tests on entry as part of the personnel selection procedure, and these results are still available for some of the cases. In this procedure the principal test used was the 1938 Raven Progressive Matrices.

In addition, cases treated at the Military Hospital for Head Injuries in 1944-45 were tested in the early stages of brain injury by the late W.R.Reynell, who used a series of tests of which the 1938 Matrices was one. It has thus been possible in certain cases to demonstrate scores on the same test (i.e., the Matrices) at different stages in the man's history - at Army entry, in the early stages after brain wounding, and several years after injury (when tested by the author).

In the case of men recently wounded in Korea no comparison has been possible between the Matrices score before and after wounding. A comparison has, however, been possible on another test. Since 1948 the Army has

Figure 2.


H.R.V.
MATRICES.
H.R.T.
DOMINOES.
40
35
30
25
20
15
10
5
0
60
50
40
30
20
10
0
20
15
10
5
0
48
36
24
12
0

used as part of its personnel selection procedure a test called the Dominoes Test. This is still a confidential test, and details of it cannot be given; it is sufficient to say, however, that it is based on the same general principles as the Matrices (i.e., it is a pattern test, but with a counting element), and is graded like the Matrices in the same percentile groupings: Grade I (S.G. I) - at or above the 95 percentile score for testees of his own age-group (intellectually superior); Grade II (S.G. II) - at or above the 75 percentile score (definitely above average); Grade III (S.G. III) - between the 75 and 25 percentile score (mentally average); Grade IV (S.G. IV) - at or below the 25 percentile score (definitely below average); and Grade V (S.G. V) - at or below the 5 percentile score (intellectually defective). The maximum point score on this test is 48.

In the above, the abbreviation S.G. refers to the Selection Grade into which Army personnel are classed according to their performance on this and other tests.

Test Recording Chart.

In order that some visual representation may be given of the presence or otherwise of intellectual impairment as shown by these tests, a chart has been constructed (Figure 2). For this purpose the scores given on the H.R.V. have been divided arbitrarily into 3 groups - i.e., scores lying between 11 and 20, 21 and 30, and 31 to 40.

The median scores in each of these 3 groups with the equivalent median scores on the Matrices and H.R.T. have been traced on the chart. On facsimiles of this chart the results of intelligence testing in the brain wounded cases can be recorded; the result of the Dominoes Test, where administered, is plotted on the 4th column.

The Effect of Re-testing in the Normal Controls.

It is of interest to compare the scores obtained on the present testing of the normal controls with those obtained at Army entry. This procedure was carried out with the Dominoes Test on 26 cases, and the results are detailed in Appendix B. The interval between the testing at the Army Primary Training Centre and when tested by the author varied between 1 and 50 months, with a median interval of 11. In 3 cases there was no change in the test scores, in 17 cases the score on the Dominoes Test increased in amounts varying from 1 to 13 points and in 6 cases the score decreased in amounts varying from 1 to 10 points. On the whole, therefore, the tendency on re-testing was for the scores to rise.

Absolute and Functional Impairment.

In all these tests, with the exception of the Matrices, the subject scored his own results. The Dominoes Test was limited to 20 minutes, so as to repeat the conditions under which it was administered on Army entry; otherwise none of

the tests was strictly timed.

In the case of the Matrices, the author scored and the subject read out his answer to each example. This formed a valuable means of studying test performance in the brain wounded cases, and patients taking an abnormally long time, experiencing difficulties, or showing carelessness in attempting the test, could be identified. In every case the aim of the testing was to see how well the patient could do, and not how badly.

Under these circumstances of testing it became obvious that two types of impairment could be recognised. In certain cases there was an absolute impairment which was shown by the inability, even when the subject was trying hard, to see through the more complex relations involved in the problem-solving tests.

In other cases a functional impairment in test performance was noted by a careless and erratic response. When this was apparent on the Matrices and the patient was producing a score lower than was thought justifiable, then he was given an opportunity to correct his mistakes once only, and a corrected score on the Matrices was obtained. This corrected score is also given in certain of the cases.

III. RESULTS.

Classification of Cases.

Cases which at the time of testing showed clinical evidence of dysphasia (either expressive or in word-finding) were treated as a separate group. Two groups were then distinguished among the cases without dysphasia - namely, a group of cases in which a clear intellectual deficit could be demonstrated; and a group in which all the evidence suggested that the patient was functioning intellectually at much the same level as before injury. The remaining cases were those in which the results of mental testing were equivocal. The number of cases in each group is as follows:

I	With unequivocal deficit	7
II	Without demonstrable deficit	38
III	Doubtful cases	15
IV	Cases with dysphasia	10

In no case was an unequivocal deficit assumed unless the score on each problem-solving test administered was much below that which would be expected in view of the vocabulary level reached. Moreover, in doing the tests, the subject had to be trying hard and to find the more complex relations genuinely difficult; taking him over his mistakes, or re-testing some time later, had not to result in any appreciable increase in the scores. In certain cases the pre-injury scores on the Matrices or Dominoes

were available for comparison. A spontaneous account of difficulty with intellectual tasks was sometimes given by the patient which provided confirmatory evidence.

This investigation had begun before the Dominoes Test became available to the author, but it has been administered to the majority of the patients. In certain cases the only information which could be obtained from the man's documents was not the actual score on the Matrices or Dominoes Test but the S.G. into which he had been placed on Army entry. This has been used as an indication of the man's pre-injury intelligence level. This S.G., however, is a composite one based on an overall assessment made from administering a battery of tests (verbal, arithmetic, etc.) of which either the Matrices or the Dominoes Test was one. Only an approximate estimation can therefore be made of the probable point scores obtained in these cases on either the Matrices or Dominoes, but the point scores on these tests which are equivalent to different S.G. levels are given for reference in Appendix C. The Medical Research Council (M.R.C.) case index number, the rank, age at wounding, date of wounding, date of testing, civilian occupation before wounding, site of wound, and the results of mental testing after and before wounding (where available) are given for each of the 70 cases in Appendix D. A general analysis of the sites of wounding is given in Appendix E.

Group I - Cases with Unequivocal Deficit.

There are 7 cases in this group (Nos. 1, 5, 8, 12, 17, 31 and 56). In each case, with the exception of No. 5, tracings of the skull radiographs in both the lateral and antero-posterior views are given (Figs. 3, 7, 9, 11, 13, 15). In Case No. 5 no skull radiographs were available, but an outline sketch of the head indicates the extent of the skull defect and its position (Fig. 5). The results of mental testing in each case have been recorded on a chart (Figs. 4, 6, 8, 10, 12, 14, 16). In the radiographs the site of skull penetration is shaded; metallic foreign bodies are dense black. Bone chips in the brain appear as triangles (where pre-operation radiographs are available). An outline of the ventricles as seen by air encephalography is sometimes shown.

In the subsequent case records the details of the site of injury may sometimes seem discrepant compared with the skull radiographs. It should be remembered that the case notes have been compiled from operation notes written in the field under active service conditions. The skull defect on the X-ray forms the best guide to the area of the brain actually penetrated by the missile, while the depth of the penetration is usually indicated by the surgeons' findings at operation.

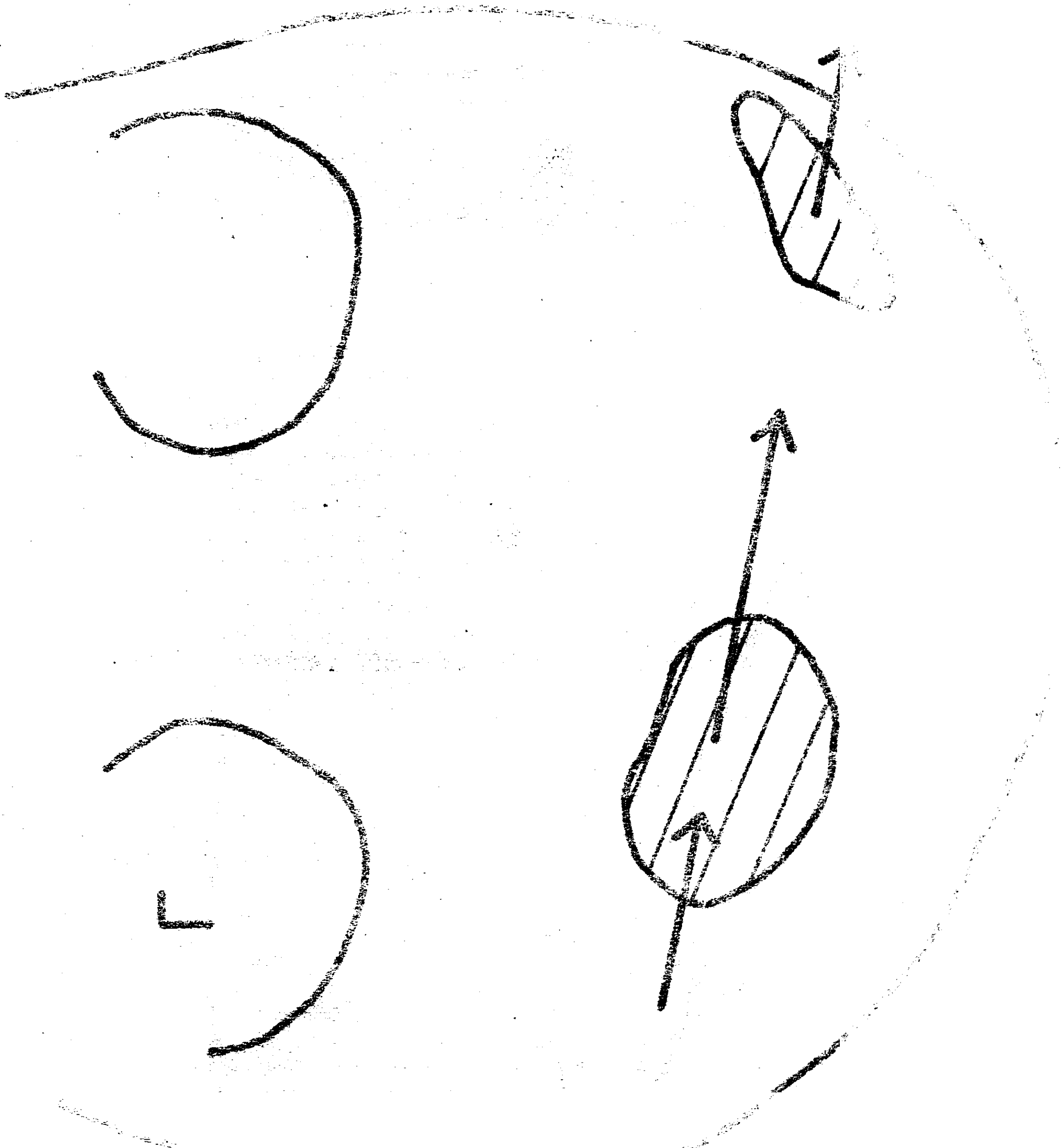


Figure 3.

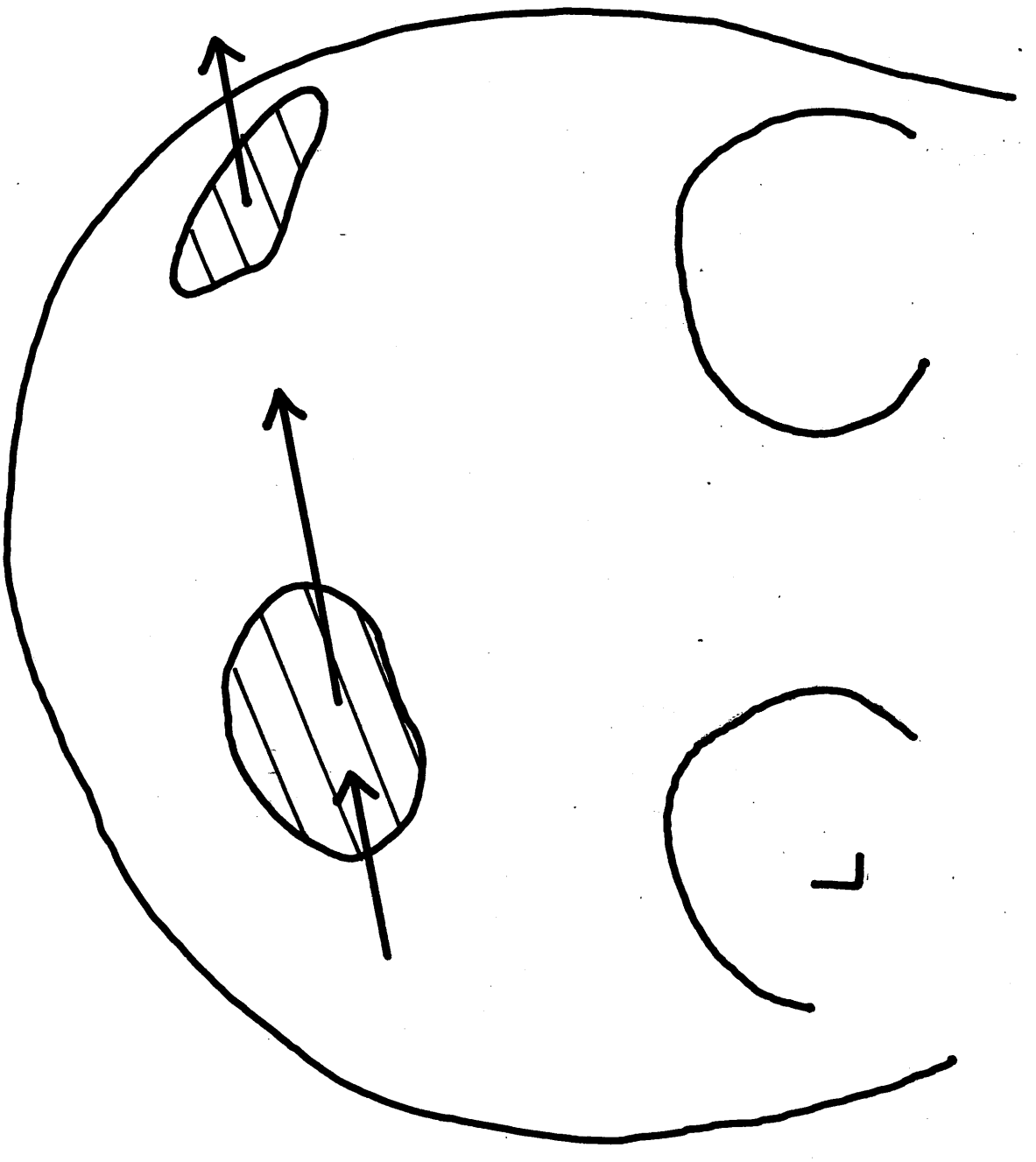
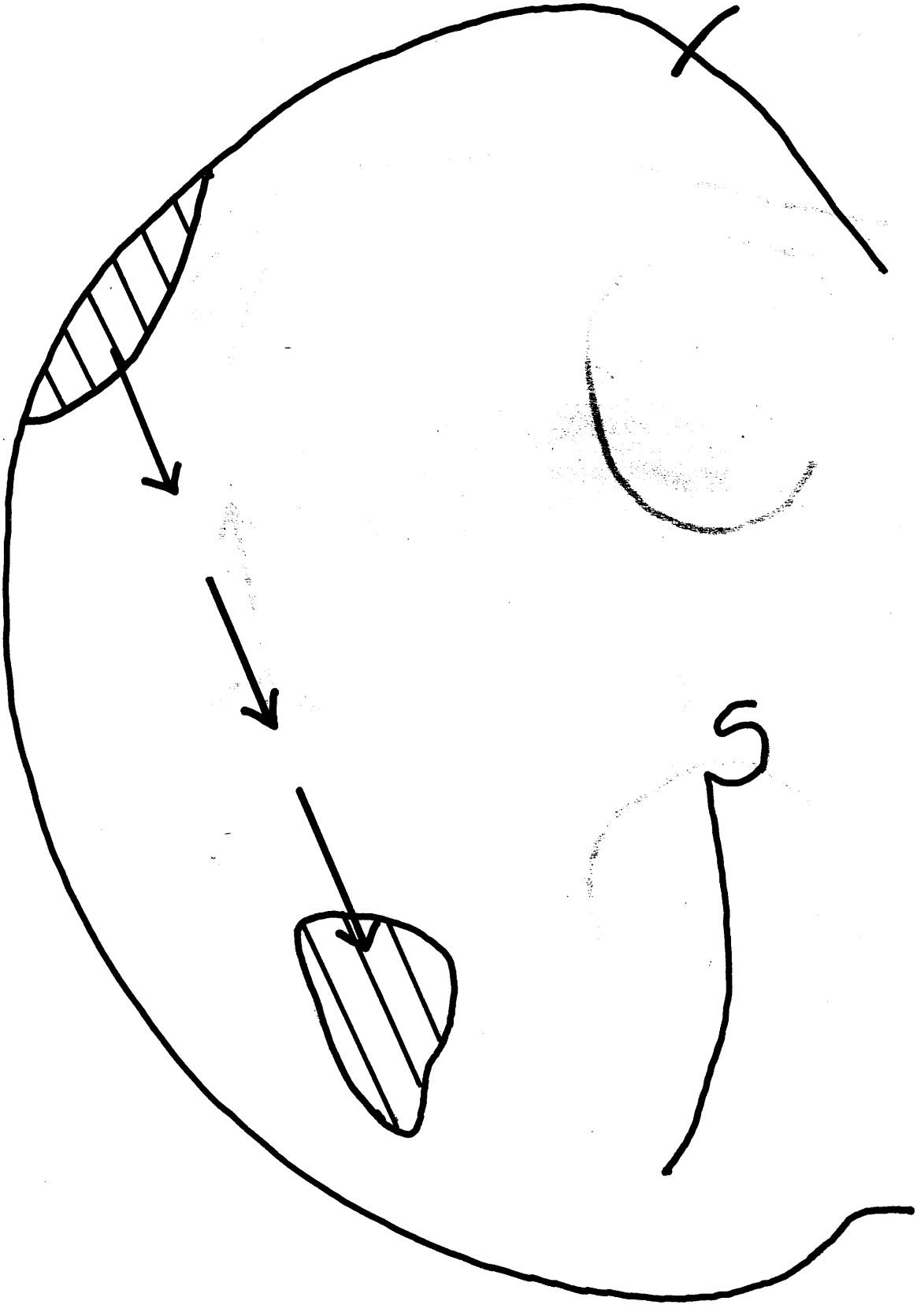


Figure 3.



Case 1 (M.R.C. No. 959).

This 23-year-old corporal was wounded in Korea by a shell fragment on 24th April, 1951. The missile entered the left parietal area, passed through and through, leaving by the right frontal area (Fig. 3). On admission to a U.S. Field Hospital on 25th April he was stuporous, but could be roused. There was divergence of the eyes, dilation of the left pupil, and left lower facial weakness, extensor rigidity of both legs, which he withdrew from pin-prick, and no movement in the left upper limb. Deep tendon reflexes were increased on the left side.

Skull films revealed a fracture of the left occipito-parietal region, with indriven bone fragments. A cranial defect was also seen in the right frontal region.

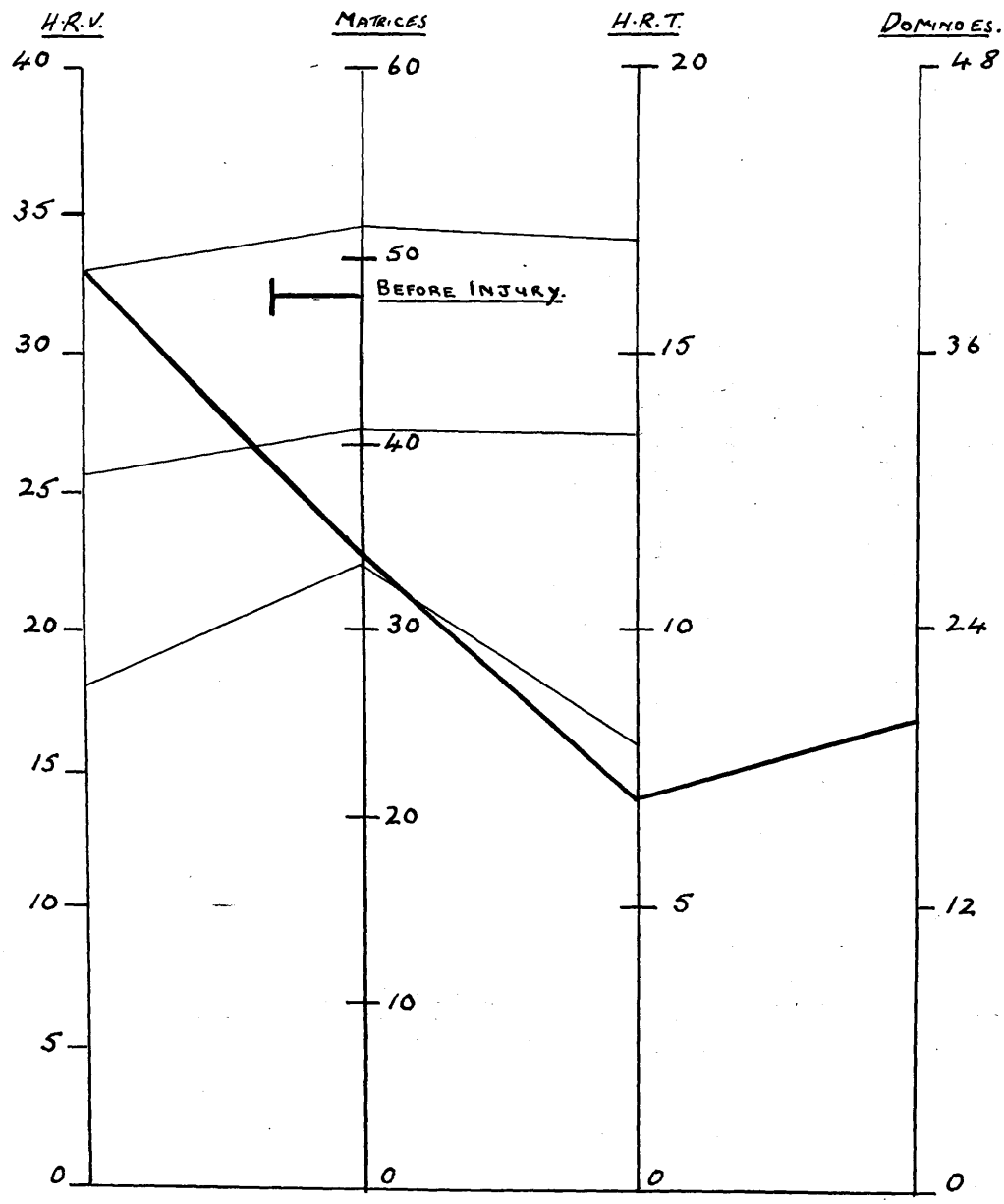
At operation on 25th April (Lt-Colonel Meirowsky) left occipital and right frontal craniectomies were performed.

Left occipital craniectomy: A moderate-sized bone defect was revealed in the left parieto-occipital region. There was marked comminution and depression, and when all extracranial pieces of bone were removed a moderate-sized dural tear was exposed from which liquefied brain was exuding. All liquefied brain tissue and a massive intracerebral haematoma were removed. Innumerable pieces of bone were encountered intracranially and removed. The track was followed to the falx, which was well visualised.

Right frontal craniectomy: Inspection revealed massive shattering of the right frontal bone. The dural tear was irregular and somewhat larger than that found at the site of the wound of entry. An enormous intracerebral haematoma was delivered. Following its evacuation a large amount of liquefied brain tissue presented itself and had to be removed by suction. A small number of comminuted bone fragments was encountered intracerebrally and these were removed. Digital palpation revealed two tracks: one leading directly to the perforation in the falx, and the other to the right occipital lobe. The latter apparently represented the cavity which had been occupied by the massive intracerebral haematoma.

On admission to the American Army Hospital on 8th May he was alert and rational but poorly orientated, but by 30th May he was completely orientated. He was admitted to the Military Hospital for Head Injuries on 31st July, 1951. On admission neurological examination revealed the presence of a left hemiplegia, with some facial weakness on the left side involving both upper and lower muscle groups. The pupils were equal and reactive. There was a spastic weakness of the left upper limb. Tone and power were normal in the right upper limb. Tendon reflexes

Figure 4.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BEFORE INJURY.

were markedly increased on the left. There was a spastic weakness of the left lower limb, with severe clonic spasm; the tone and power of the right lower limb were normal. There was a left extensor plantar response. He was subject to occasional focal sensory attacks affecting the right arm and leg, but no general convulsions. In the early stages of his injury he showed some difficulty in spatial orientation but this gradually improved and was not apparent on specific testing. He was right-handed.

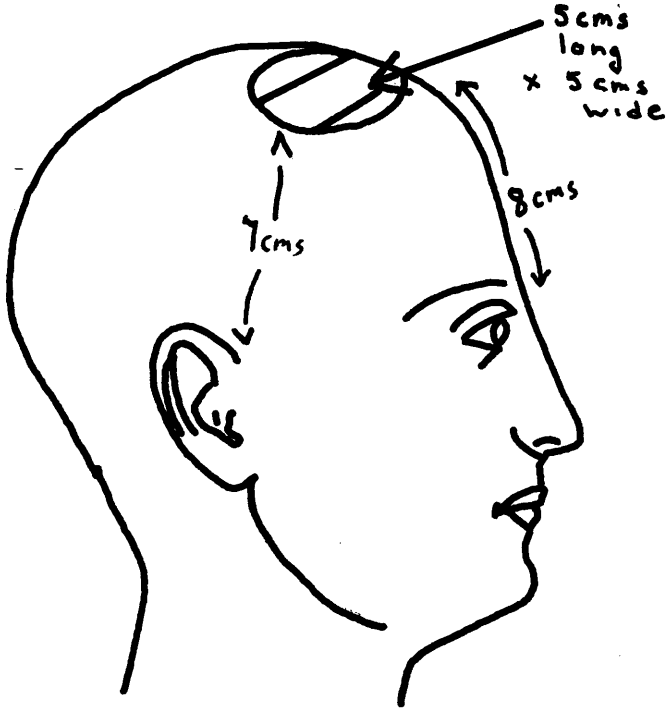
He was first seen by the author in October 1951. The last thing he remembered before the wound was the man next to him being shot and the enemy all around them (retrograde amnesia a few minutes). He did not remember actually being hit. His first clear memory subsequently was of being in the American Hospital in Tokyo (post-traumatic amnesia 3 weeks). He complained of slowness in thinking and found difficulty in doing the anagrams in the crossword puzzles. He also complained that he could not calculate as well as before the injury and could not remember if there were 10 or 12 pennies in a shilling.

Intelligence testing, which was first carried out on 20th March, 1952, almost a year after injury, revealed a severe and absolute intellectual loss (Fig. 4). His scores were: H.R.V. 33, Matrices 34, H.R.T. 7 and Dominoes 20. It is significant that he failed on all three problem-solving tests at the same level, whether such tests involved visual patterns (Matrices) or the manipulation of verbal material (H.R.T.). He was unable to see through the more complex relationships and solve the more difficult problems. In all tests he tried very hard, and his disappointment and frustration were obvious when he realised his ability to perform these tests was much below his own expectation. This contrasted with the rapidity with which he was able to do the vocabulary test. His score on the Matrices (34) was well below that which he had produced on Army entry $4\frac{1}{2}$ years previously(48).

His present scores on the Matrices and Dominoes Test placed him in S.G. IV in each case. His score on the Matrices on Army entry in September, 1947, placed him in S.G. III+. His scores in the battery of tests (Matrices, arithmetic, verbal, etc.) then administered gave him an overall S.G. of II. He was regarded as above average in education and intelligence. Before joining the Army he was a draughtsman and had taken a National Certificate in mechanical science.

In spite of this decrease in his ability to perform problem-solving tests, his ability to read and use verbal material was quite intact. He was able to give a full

Figure 5.



account in words of anything he might wish to communicate, with no apparent defect. Indeed, his descriptive powers were excellent and had a graphic quality: when describing his experiences in Korea, he spoke of the "plasticine figures lying wounded on the battle-field, with their heads turned to one side, and not being able to get at them, as the ground was strafed with machine-gun fire".

Case 5 (M.R.C. No. 966).

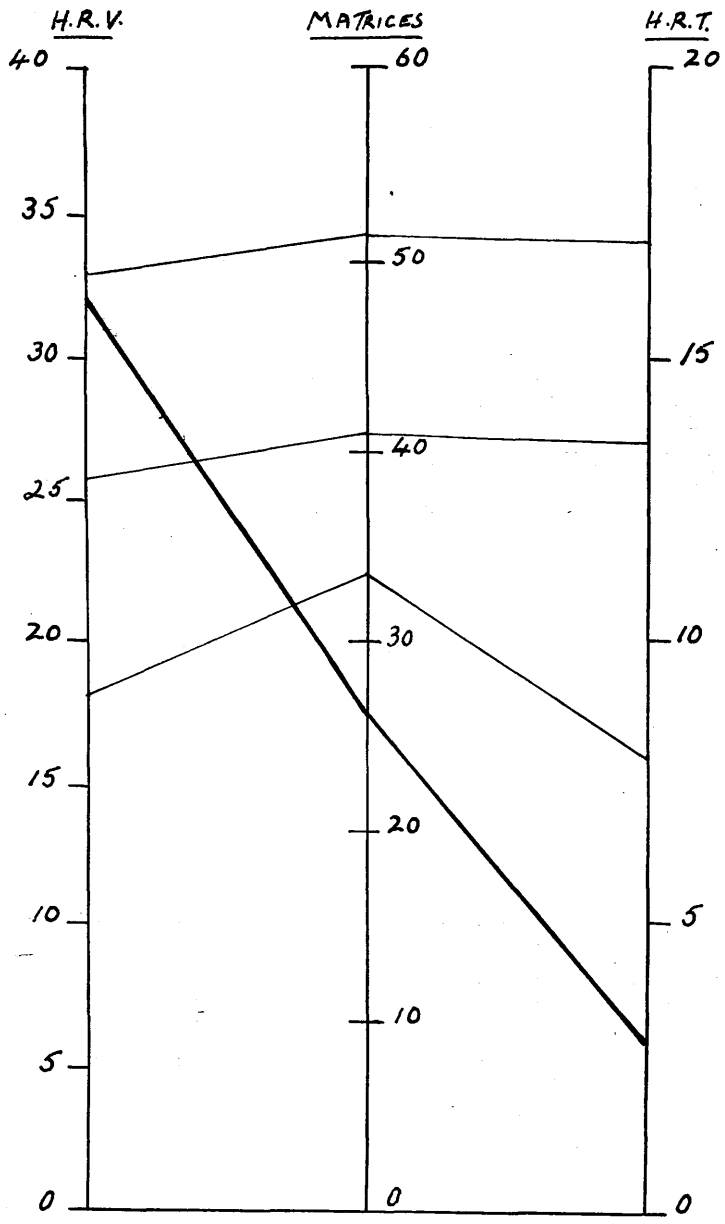
This 36-year-old fusilier was wounded in Korea by shrapnel on 3rd January, 1951. He remembered the shell exploding above his head, being hit and then falling to the ground. He was dazed for about five minutes, but did not lose consciousness (no R.A. or P.T.A.). His right eye became red and painful and the vision in it was completely lost in three days.

He was admitted to a U.S. Field Hospital on 6th January, 1951. On admission there was a stellate laceration in the mid-portion of the right frontal area. Skull films revealed a comminuted depressed fracture with four sizeable bone fragments within the frontal lobe tissues, as well as a small piece of shrapnel, all situated at a depth of 4 cm.

At frontal craniectomy performed on the same day (Lt-Colonel Meirowsky) the perforation in the outer table of the frontal bone measured 0.5 cm. in diameter, while the inner table was heavily comminuted and the underlying dural perforation measured 1.5 cm. in diameter. Exuding through this dural laceration were necrotic brain tissue and clots. In front of the dural tear there was extensive maceration and liquefaction of the frontal lobe tissue. The shrapnel canal was filled with necrotic brain, blood clot, four comminuted bone fragments, and a small piece of shrapnel, all of which were removed. The canal measured 4 cm. in depth and 2 cm. in width.

He was admitted to the Military Hospital for Head Injuries on 30th March, 1951. He was left-handed by preference, using the left hand for chopping and throwing a cricket-ball, while he was right-handed for writing, by practice. He was alert and fully orientated and had no complaints. There was a skull defect 5 cm. in diameter in the right posterior frontal region, 7 cm. above the external auditory meatus and 8 cm. behind the root of the nose (Fig. 5). There was no anosmia. This vision in the left eye was normal, but the pupil of the right eye was obliterated by scarring (this eye was eventually enucleated). There was a slight emotional left facial weakness, but no weakness of the limbs apart from a slight

Figure 6.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left hypotonia. There was no sensory deficit.

He was discharged from hospital in May, 1951, and returned in March, 1952 for a repair of the skull defect. An air encephalogram was then carried out which showed good filling of the ventricular system, without a significant shift, but there was a localised dilatation of the right ventricle anteriorly. Traumatic epilepsy had not developed.

Intelligence testing was carried out on 24th March, 1952, fifteen months after injury (Fig. 6). His approach to testing was good, although he obviously found it difficult. His scores were: H.R.V. 32, Matrices 26, H.R.T. 3. The Dominoes Test was not done. No pre-injury scores could be obtained in his case. Before entering the Army he had been employed as a heavy transport driver. He left school at 14; according to his own statement, he was an average, but by no means a poor, scholar.

Case 8 (M.R.C. No. 928).

This 34-year-old sergeant sustained a self-inflicted wound in Germany on 5th March, 1948. The bullet entered the right frontal region 3 cm. behind the right eyebrow, passed through and through, and made its exit by the right parietal region, superiorly.

On admission to a Military Hospital in Germany he was comatose, with the right pupil larger than the left. There was a left lower facial weakness, otherwise the cranial nerves were normal. The left extremities were flaccid, and there was a general hyporeflexia with flexor plantar responses. There was no sensory deficit.

At operation 8 hours after wounding the wounds were joined across the parietal bone, which was widely exposed. In the area of the exit wound there was a tear in the dura the size of a shilling, through which brain was pouring.

Two days later an equivocal left extensor plantar response was elicited, and his course proceeded steadily downhill. However, from 13th March he began to improve, and by 31st March he was stated to be rational.

He was admitted to the Military Hospital for Head Injuries on 23rd April, 1948. He remembered everything up to going to bed the night before the injury (R.A. 13 hours); his next memory was of waking up in hospital in Germany (P.T.A. 2-3 weeks). There was no visual field defect, and his taste and smell were normal. His speech was normal and he gave a good account of himself, but was slow in expression;

Figure 8.

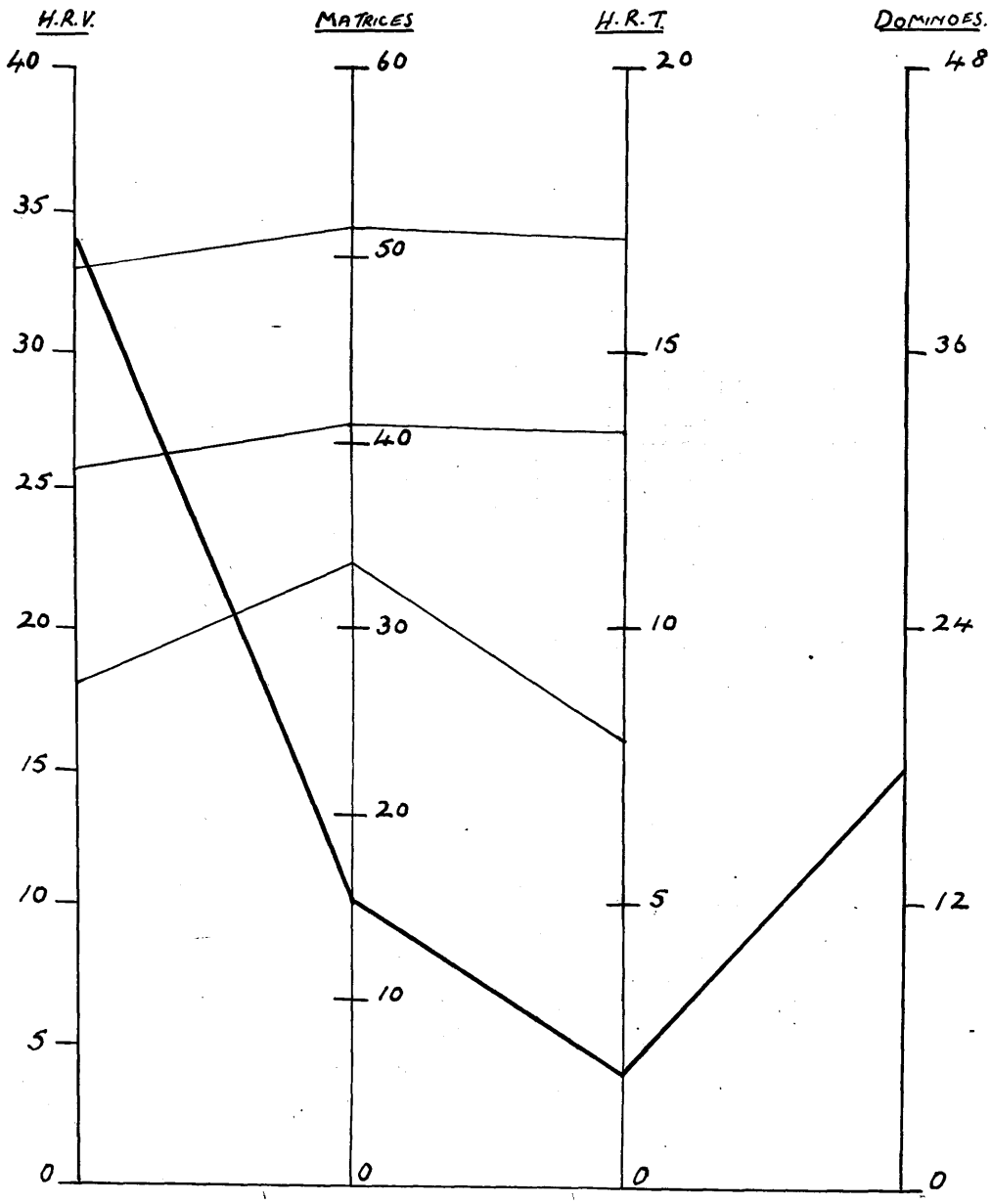
H.R.V.
MATRICES
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Figure 7.

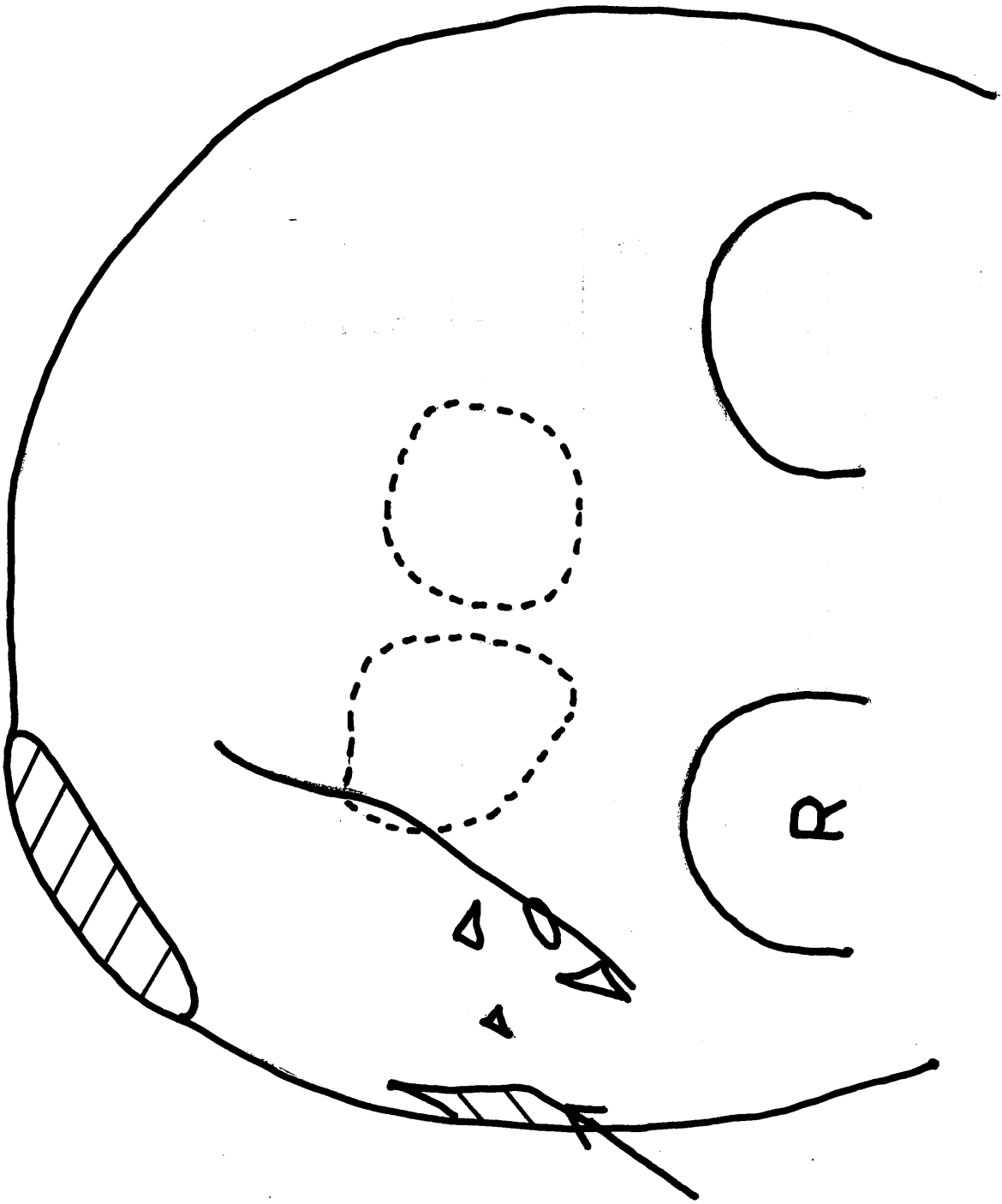
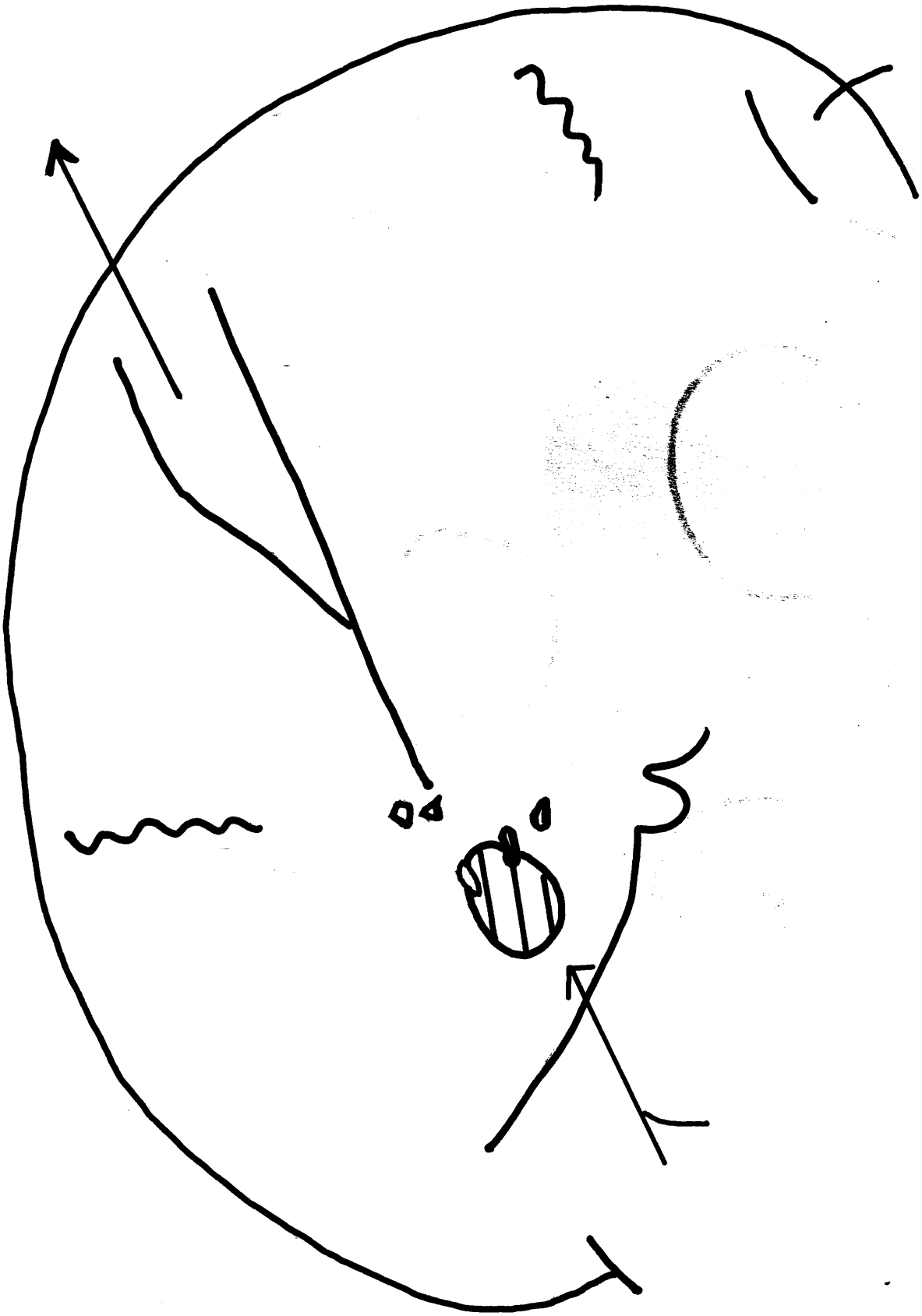


Figure 7.



he was also slow in performing simple mental tasks. The pupils were equal and reacted to light. There was a slight lower facial weakness. He had a severe left flaccid hemiplegia becoming spastic, most severe in the arm, with cortical sensory loss on the left. There was an extensor plantar response on the left, and sustained clonus. He was right-handed.

Skull films taken on 4th May, 1948, showed a wound of entry in the right temporo-parietal region, and a wound of exit in the right parietal bone. There were numerous fracture lines on the right side, and numerous intracranial bone chips in the region of the right Sylvian fossa. There were no metallic foreign bodies (Fig. 7). An A.E.G. performed on 23rd July, 1948, showed both ventricles containing air, the right more than the left. The right ventricle appeared larger than the left, but the left posterior horn only was shown. Both lateral ventricles showed a slight shift to the right.

During his progress in hospital his speech was noted to be explosive at times, but there was no dysphasia. He developed attacks of traumatic epilepsy which began with focal twitching in the left leg, followed by loss of consciousness. His wife stated that he was definitely changed mentally and was slower and more childish. He spent most of his time reading novels. In March, 1949, he was transferred to Headington Hill Hall.

Intelligence testing was carried out on 10th April, 1952, four years after injury (Fig. 8). He showed a severe loss in the ability to do problem-solving tests. His scores were: H.R.V. 34, Matrices 15, H.R.T. 2, and Dominoes 18. No pre-injury scores could be obtained in his case. He left school at 14 and he was considered to be a good scholar. He was a regular soldier.

Mentally he appeared very simple, and it was with some surprise that it was noticed that he continually kept a supply of all the best current books on his bedside table, books such as Churchill's Memoirs and novels by Graham Greene. He was able to discuss the books he had read recently and could relate their contents with surprising accuracy. Yet in the occupational therapy department he was wholly unable to work out for himself small problems which occurred in the course of his work. He was unable to do anything really constructive, and his activities were confined mostly to repetitive tasks.

This preservation of his ability to use and understand verbal material, in spite of a severe and otherwise deteriorative injury, is further illustrated by two of his productions reproduced in Appendix F. The first is a

Figure 9.

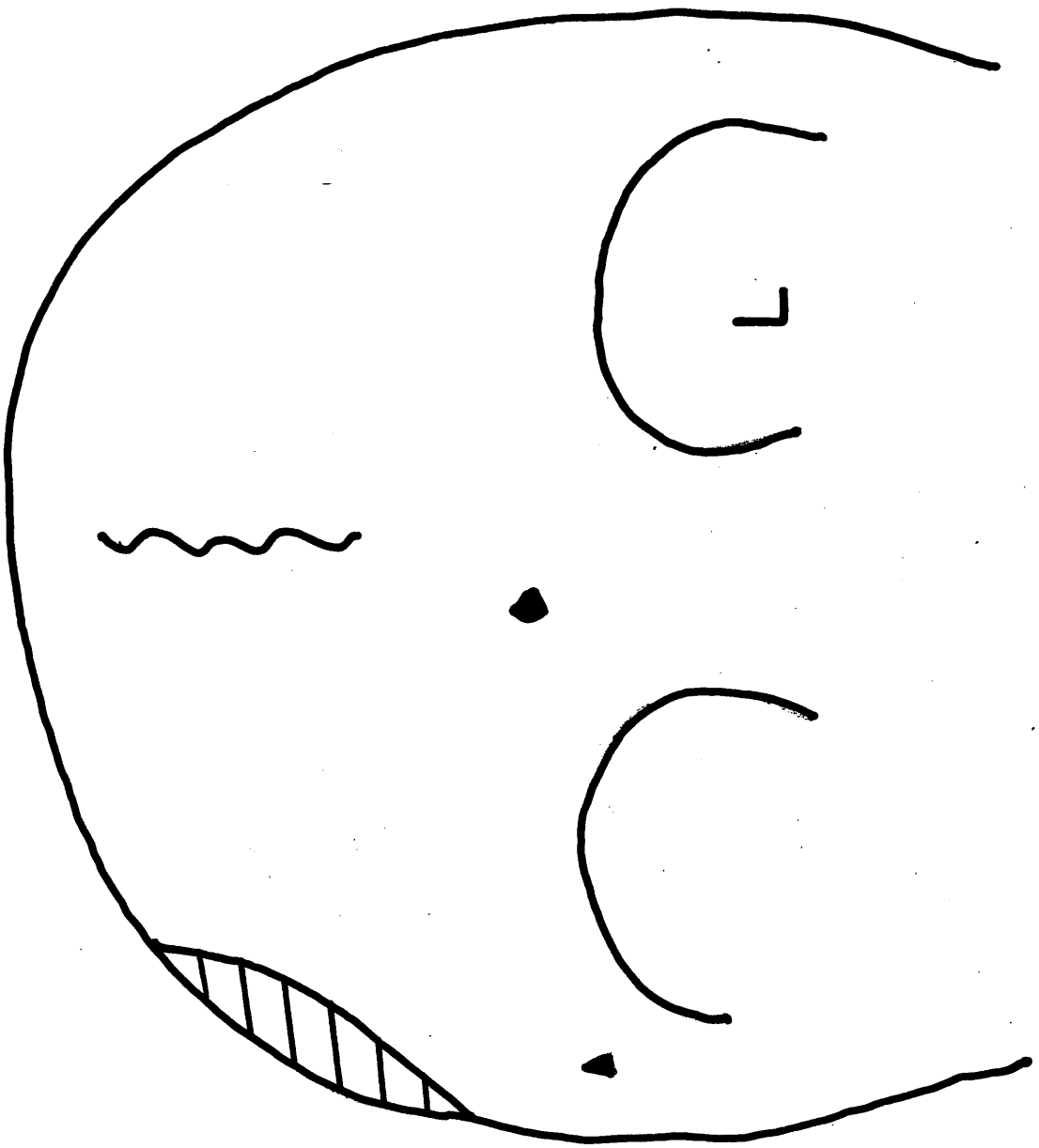
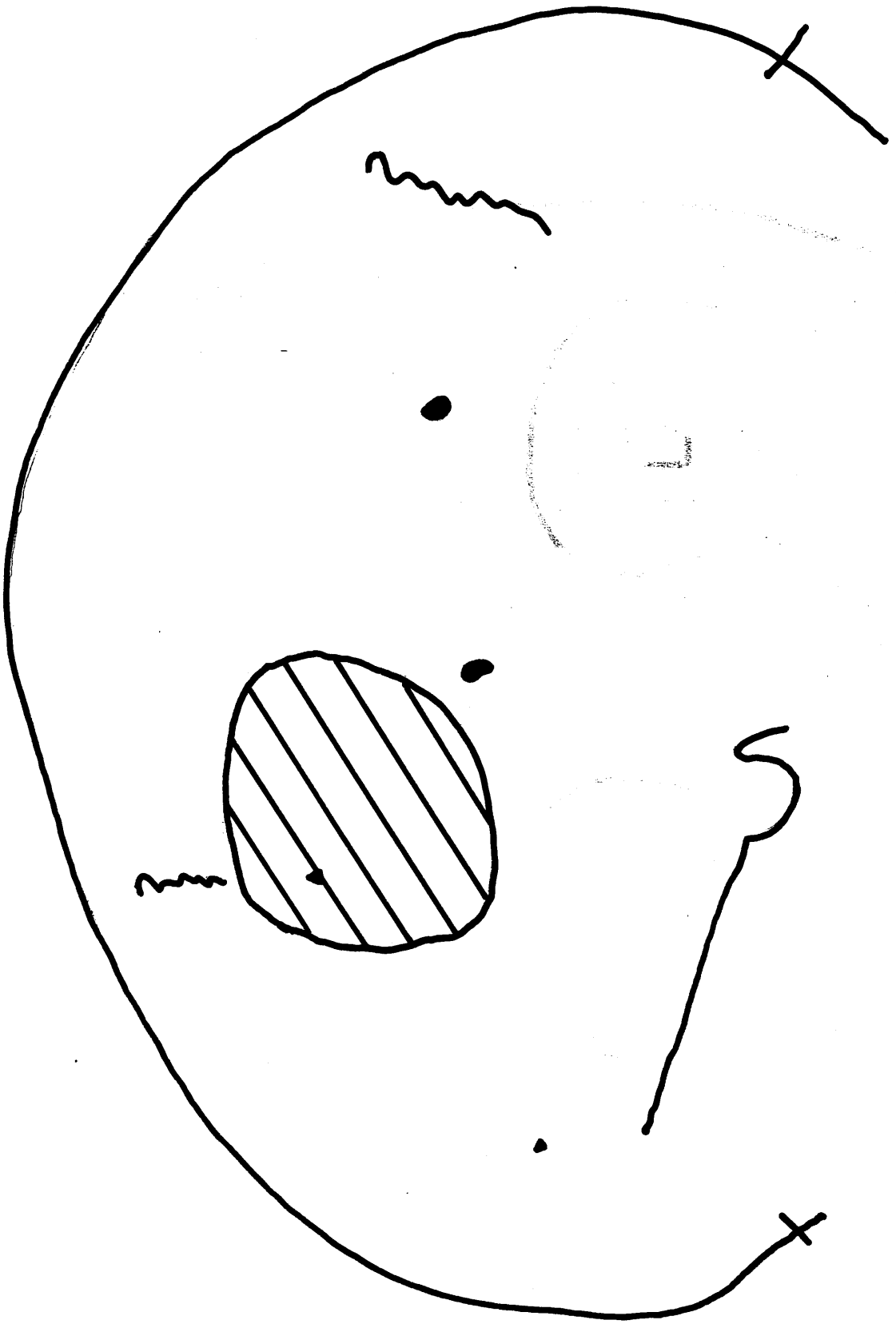


Figure 9.



transcript of an article which he wrote for "Neurone News", the departmental newspaper. There are undoubted defects in this article, both in style and construction, but it shows the retention of considerable verbal facility. The second is an account which he wrote on request after reading a book called "One of Our Submarines".

Case 12 (M.R.C. No. 960).

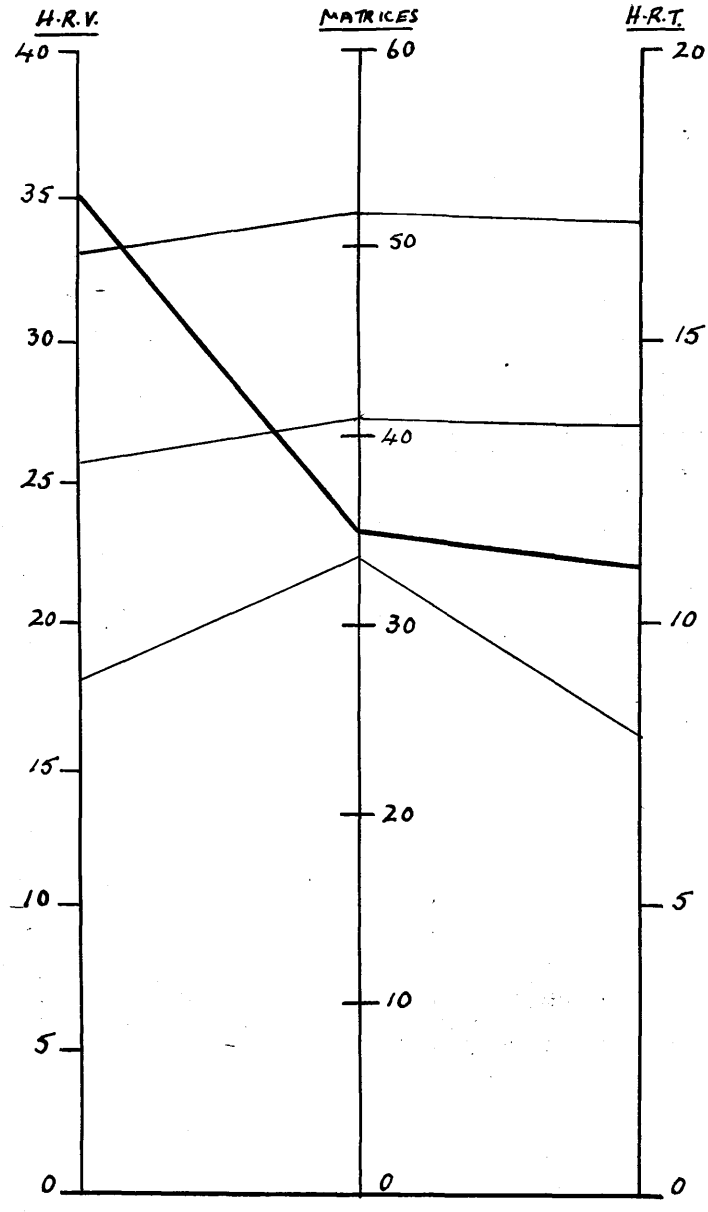
This 30-year-old corporal was wounded in Korea by a shell fragment on 3rd January, 1951. On admission to a U.S. Field Hospital on 5th January he was noted to have a penetrating scalp wound, about 1.5 cm. in diameter, just behind the coronal suture in the right anterior parietal region. He was very lethargic, could be aroused, but was not well orientated. There was a left hemiparesis which was most marked in the hand. Skull films showed a depressed and comminuted fracture of the right parietal bone, with several foreign bodies and bone fragments within the frontal lobe.

At operation performed on the same day (Lt-Colonel Meirowsky) a small perforation in the anterior and inferior portion of the right parietal bone was revealed 1 cm. medially to the insertion of the temporal muscle. There was a dural laceration 2 cm. in diameter underlying this. When the edges of the laceration were debrided and the dural opening enlarged massive amounts of blood clot and liquefied cerebral tissue exuded from the shrapnel canal under tremendous pressure. Mixed with the necrotic brain and subcortical haematoma were seven comminuted fragments of bone; all these were removed. The shrapnel canal extended to a depth of 6.5 cm. A rather extensive subdural haematoma overlying the mid-portion of the right cerebral hemisphere was then evacuated.

Post-operative X-rays showed a surgical defect in the right parietal region measuring 4 x 5 cm. There were some tiny foreign bodies remaining in the scalp and one in the midline of the brain. No pieces of bone remained (Fig. 9).

His post-operative course was uneventful. His left-sided weakness, which had been most marked in the upper limb, being complete in the hand, improved slowly for the first few days after operation, and then within a 24-hour period made a dramatic and almost complete recovery. When he left the American hospital on 15th January the only neurological deficit was a minimal left lower facial weakness, very slightly increased tone and impairment of coordination in the left upper limb, and hypoactive abdominal reflexes.

Figure 10.


H·R.V.
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He was admitted to the Military Hospital for Head Injuries on 25th February, 1951. He complained of difficulty in forming words, especially when emotionally disturbed, and stated that he had difficulty with speech in the first 3 days after wounding; but when given specific dysphasia tests he only misnamed one out of 20 objects. He was right-handed, but left-footed. The R.A. was estimated as a few seconds, the P.T.A. as 5 days. There was no anosmia or visual field defect, but some bilateral papilloedema, which was subsiding. There was a detectable loss of power in the left arm in practically all movements, but most marked distally; the degree was slight. Tone was slightly increased and the deep tendon reflexes were exaggerated in the left arm. Fine movements in the left hand were definitely clumsy.

Sensation was normal to pin-prick and cotton-wool, but there was impairment distally in the left arm to figure-writing and two-point discrimination. There was astereognosis of the left hand.

A few months after discharge from hospital he reported seizures, with turning of the head to the left followed by loss of consciousness and difficulty in speaking for half-an-hour after recovery. He returned to his former occupation as a clerk and found himself less efficient at his work than he used to be.

He came back to hospital for review sixteen months after injury (19th May, 1952), when intelligence testing was carried out (Fig. 10). He experienced real difficulty with the problem-solving tests, and his scores were: H.R.V. 35, Matrices 35, H.R.T. 11. The Dominoes Test was not done. No pre-injury scores could be obtained in his case. He left school at 16, after a secondary education, and was a clerk before joining the Army as a regular soldier at the age of 19. He had returned to civilian employment as a clerk at the end of the 1939-45 war and was wounded in Korea after he had been recalled to the Reserve.

He was regarded as above average in ability at school and in the Army had gained a first-class certificate in education.

Case 17 (M.R.C. No. 963).

This 29-year-old corporal was wounded in the left fronto-temporal region by a mortar fragment on 14th March, 1944, in Italy. On admission to a C.C.S. 1½ hours after wounding he was conscious and remained conscious during his stay, but he was dazed and speechless for several hours. There was weakness and numbness of the right hand.

Figure 12.

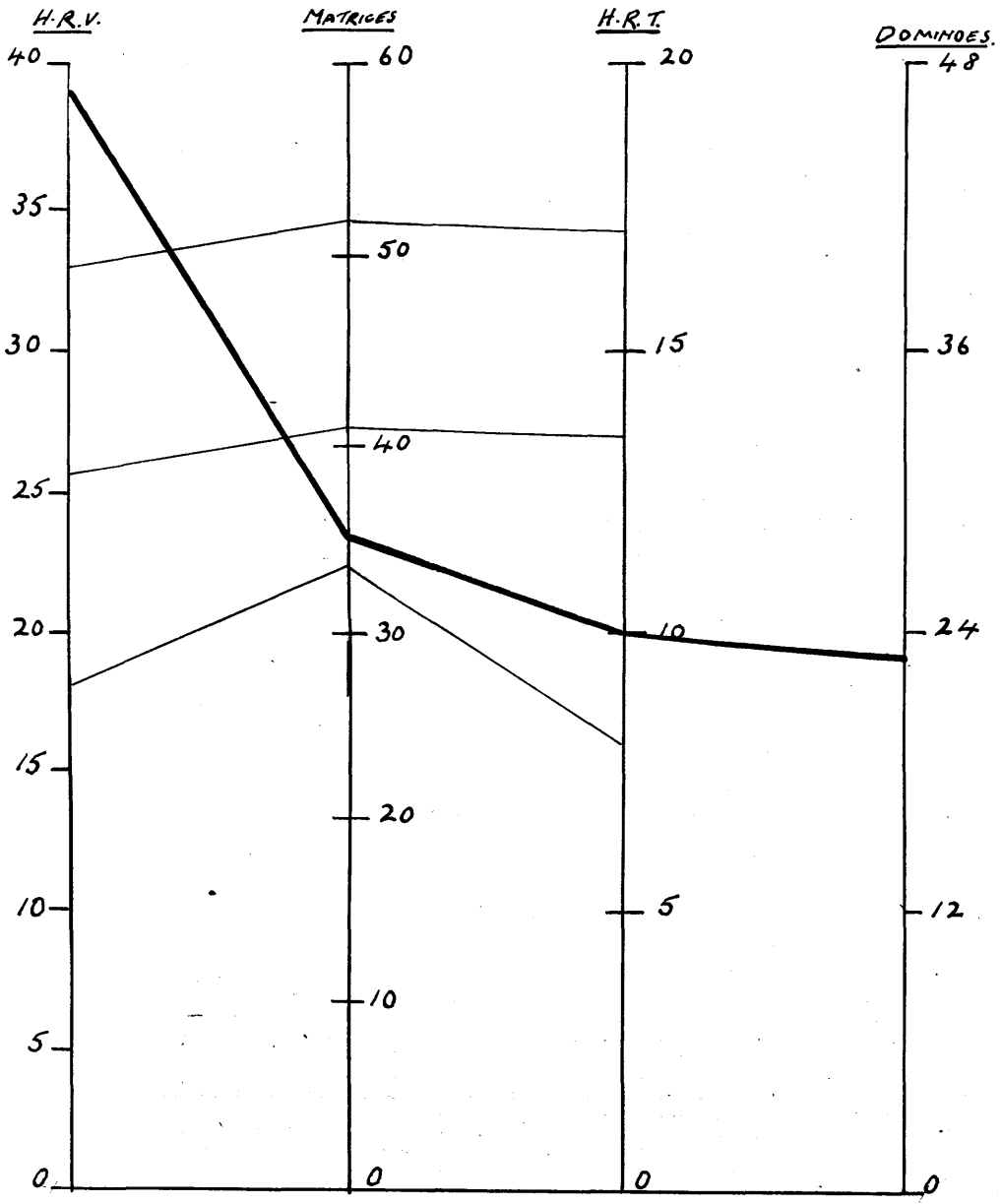
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Figure 11.

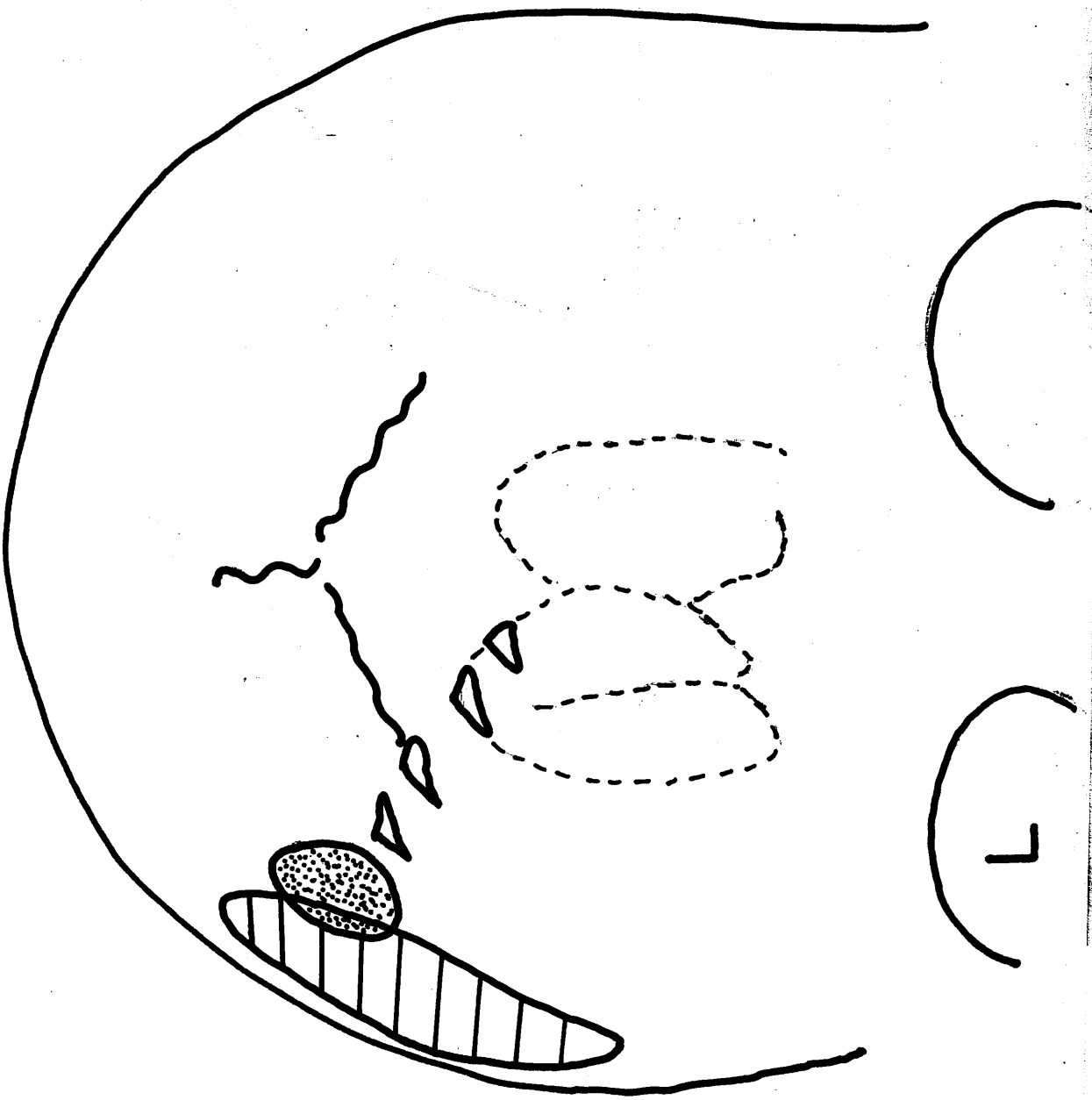
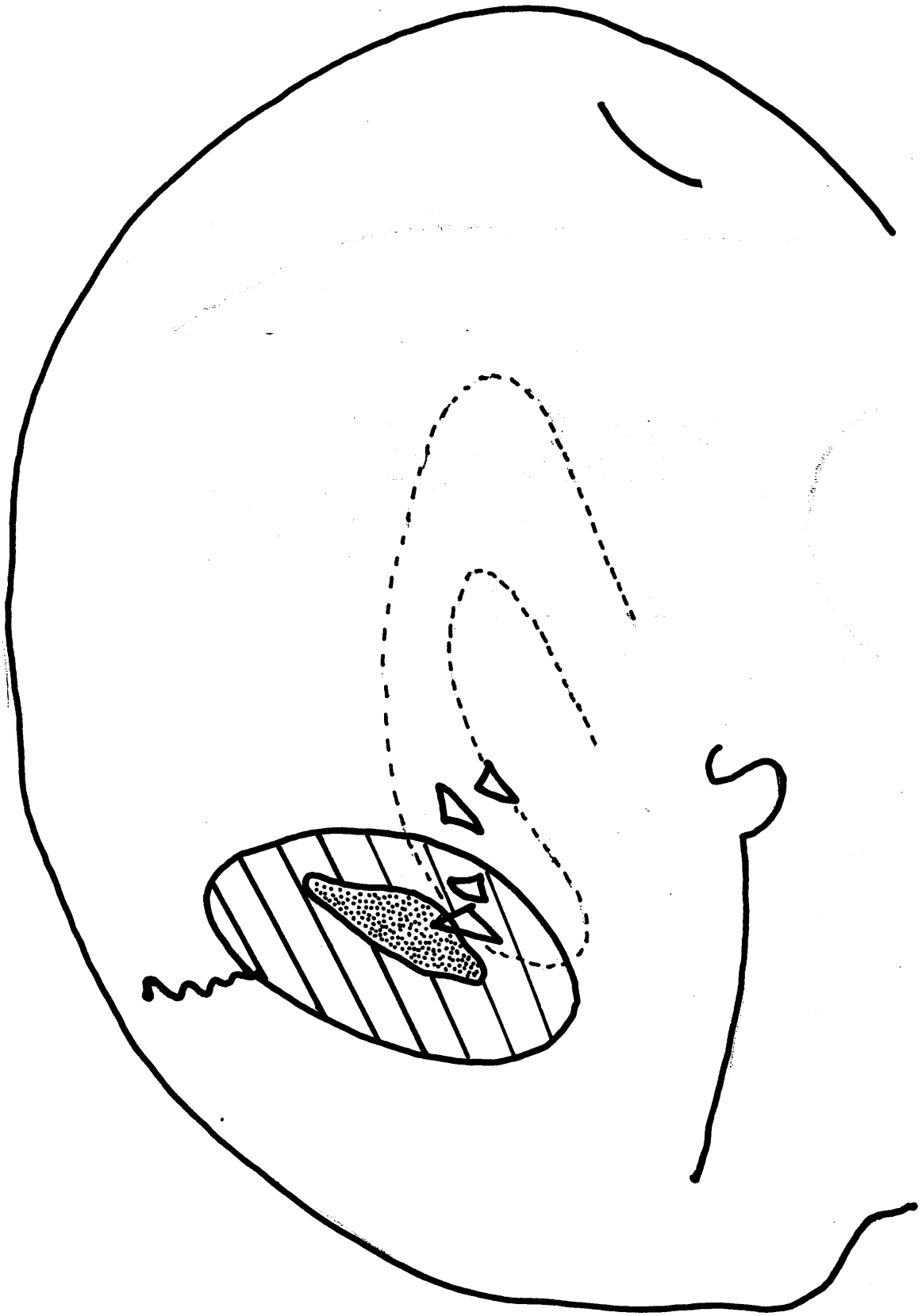


Figure 11.

The stippled area represents the size of the bone defect before operation.



On admission to No. 5 M.N.S.U. on 17th March his general condition was good, but he complained of headache and mentally he was slightly confused. His right arm was paretic with sensory change.

Skull films showed bone fragments indriven to a depth of 5 cm. (Fig. 11). At operation on the same day (Major J. Schorstein) the skull defect was enlarged and bone fragments and brain debris were removed.

He was evacuated to England and admitted to an E.M.S. hospital in May, 1944. R.A. and P.T.A. were not estimated. An A.E.G. was carried out in June, 1944; this showed all four ventricles well filled, but the left lateral ventricle was slightly dilated and the lateral part of the body extended slightly upwards and laterally towards the defect in the skull.

He was discharged home in July, 1944, and resumed his civilian employment as a sanitary inspector.

He was admitted to the Military Hospital for Head Injuries in July, 1952, for a review of his case. The neurological signs which were observed in the early stages of his injury were no longer present. He was right-handed. There was no clinical evidence of dysphasia, but he tended to stutter when emotionally excited and had occasional difficulty in word-finding. He complained of headaches and a severe inability to concentrate. He had been studying for the Meat Inspectors' Certificate since his wound and found this relatively simple examination impossible to pass. He had no difficulty in doing his routine work, but was slow at "thinking-out" his reports or letters, and his colleagues in the office would have their secretarial work finished long before he had started. An A.E.G. showed both ventricles a little larger than normal, the left larger than the right, with a shift to the site of the wound. There was no history of fits.

Intelligence testing was carried out on 7th July, 1952, 8 years after wounding (Fig. 12). He found considerable difficulty with the problem-solving tests, and his scores were as follows: H.R.V. 39, Matrices 35, H.R.T. 10, and Dominoes 23.

He left school at the age of 16 with a School Certificate with passes in 6 subjects. He qualified in 1938 as a sanitary inspector without difficulty. No pre-injury scores could be obtained in his case.

Figure 14.

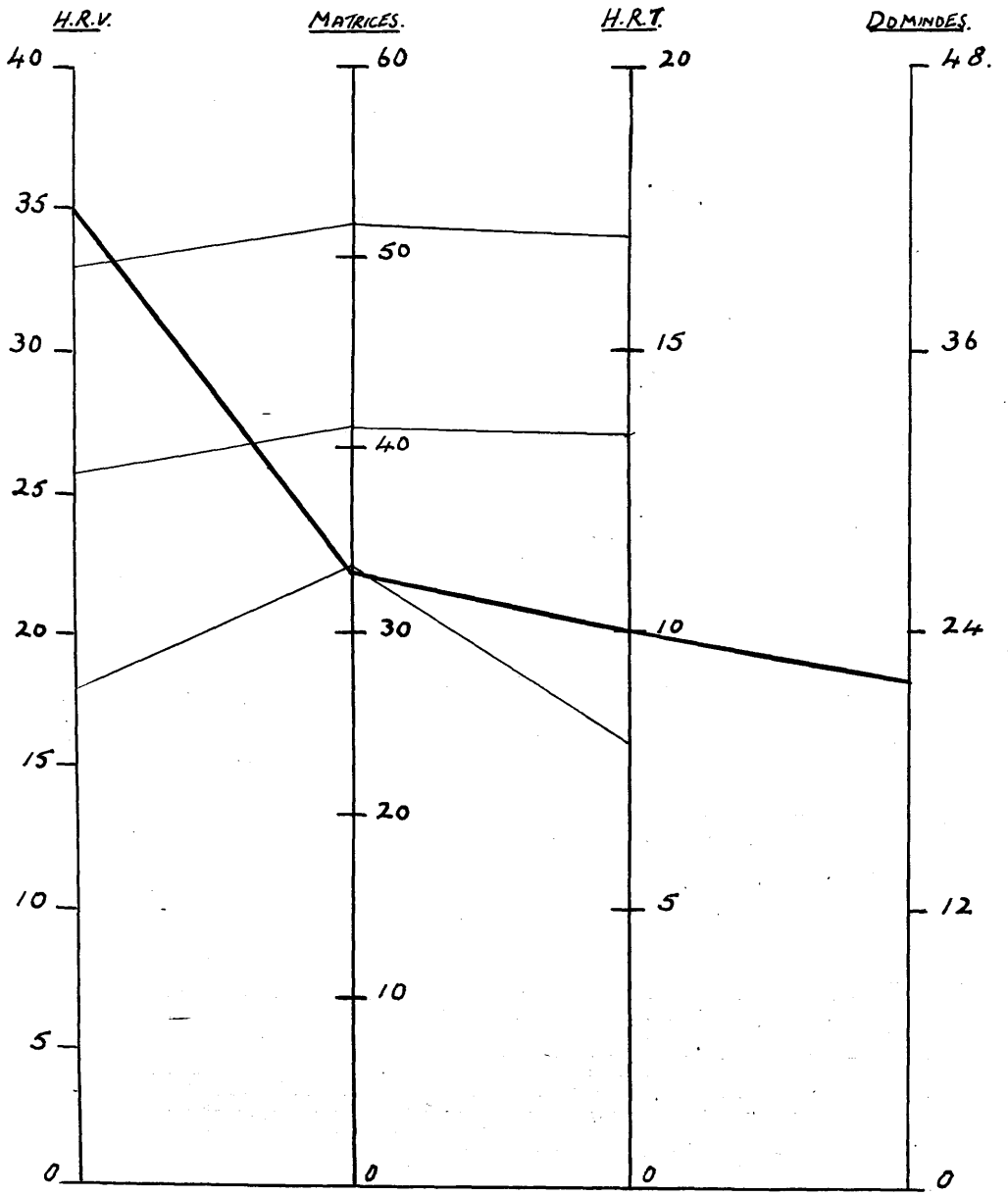

H.R.V.
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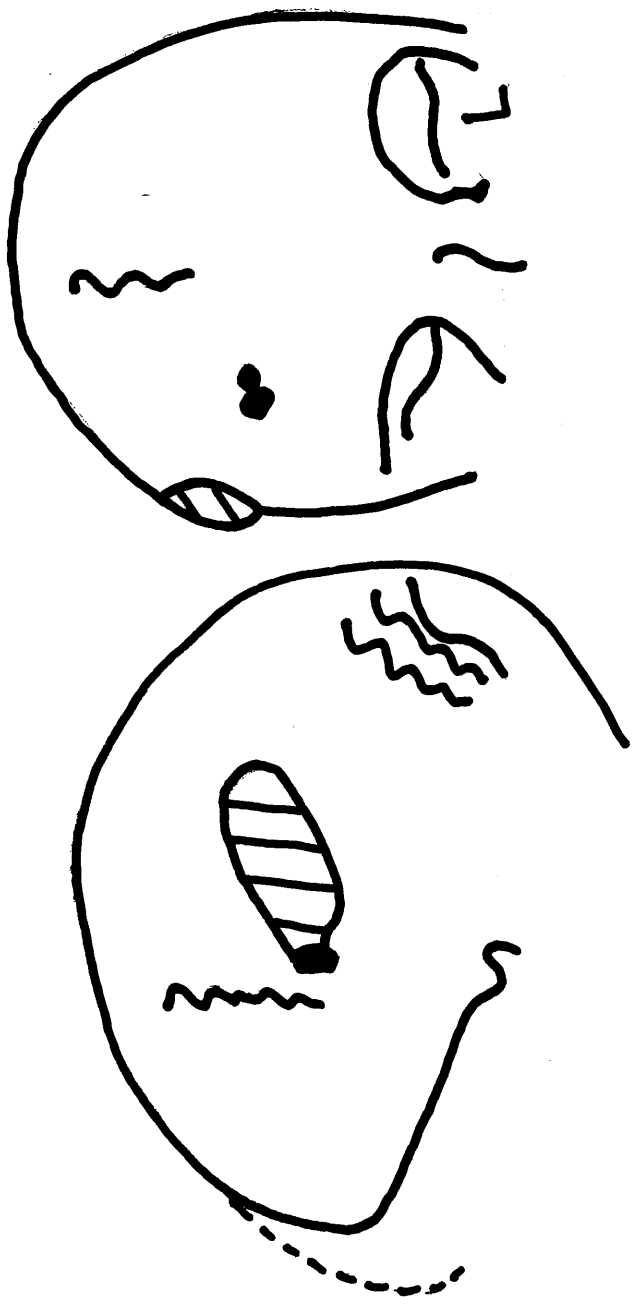
Figure 13.



Case 31 (M.R.C. No. 100).

This 32-year-old sergeant was wounded in France on 13th July, 1944. On admission to No. 6 M.N.S.U. on the same day there was a penetrating wound in the right parietal region about 2.5 cm. across. There was no loss of consciousness at the time of injury, but he had become progressively drowsy since. There was no dysphasia. He had a left facial paralysis, a complete paresis of the left arm, and a paresis of the left leg. The paresis was most marked in the face and arm. There was gross cortical sensory loss in the arm and leg.

At operation (Captain Turner), when the dura was exposed, a large vein was seen to pass downwards and forwards across the field, and this was considered to be the posterior central or central Rolandic. In front of the vein a track passed downwards in three parts; the posterior was 5 cm. deep, while the others were infero-anterior and less deep. Metallic foreign bodies and bone chips were removed.

He was admitted to the Military Hospital for Head Injuries on 15th July. He was conscious, but had severe headache (no R.A., no P.T.A.). He gave his name, number, and home address correctly, his civilian occupation, and the year he joined the Army. He was right-handed. There was a general left-sided hemianaesthesia involving the face. There was gross left facial weakness, complete paralysis of the left arm, with slight spasticity, and complete flaccid paralysis of the left leg. No visual field defect.

Skull films showed an operative defect in the lower part of the right parietal bone measuring approximately 5.5 x 3 cm. There was no evidence of indriven bone, but 3 M.F.B.s remained, the deepest at approximately 4.5 cm. (Fig. 13).

He was admitted to Headington Hill Hall for review in September, 1952. The left-sided weakness had much improved and was now most marked in the arm. There was complete left hemianaesthesia, involving the face, trunk, arm and leg, and gross astereognosis of the left hand. In the early months after injury he had attacks of traumatic epilepsy beginning with difficulty in speech, tonic adversive turning of the head and eyes to the left, and loss of consciousness; there had been no attacks since 1946.

Intelligence testing was carried out on 12th September, 1952, 8 years after injury (Fig. 14). His approach to testing was good, but he did not find it easy - "I can't make head or tail of the difficult ones". His scores were: H.R.V. 35, Matrices 33, H.R.T. 10, and Dominoes 22.

No pre-injury scores could be obtained in his case. He complained that if he had something to do it took him a long time to sort it out; he was not like this before. His wife had noticed that since his wound he was much slower mentally, and she now had to accept responsibilities which normally he would have taken in his stride. He left school at 14, an average scholar, and took a technical training in brick-laying; this involved studying elementary mathematics and science. He attended a technical college from 16 to 19 and took the East Midlands certificate in his trade.

Case 56 (M.R.C. No. 1004).

This 19-year-old private was wounded by mortar fire in Korea on 10th April, 1953. On admission to a U.S. Field Hospital on the same day he was comatose, with a fungating wound behind the right ear measuring 4 x 1.5 cm. and running coronally. The right pupil was widely dilated and fixed; the left pupil was 5 mm. in diameter and fixed. He was at first flaccid and non-responsive and subsequently became decerebrate. Tendon reflexes were hyperactive throughout, with absent superficial reflexes and bilateral extensor plantar responses. He responded to pain throughout with decerebrate activity.

Skull films showed a depressed comminuted fracture of the right posterior temporo-parietal region, with a bone fragment at midline directly in from the wound of entrance. A large M.F.B. and a smaller one in the midline lay just beneath the frontal skull at the bregma.

The patient was considered to be non-operable on admission, but as he continued to live he was operated on the next day.

Craniectomy (Major A.F.Kingman): Bifrontal burr-holes were made just behind the hair-line, and a subdural haematoma approximately 50 c.c. in volume was found on the right. The subdural space was clear on the left. The wound behind the right ear was debrided and a scalp flap turned. The underlying fracture was found to measure 3 x 1.5 cm., with linear fractures extending from it in all directions. The dural tear measured 3 x 1 cm., and when the missile track was entered a large amount of necrotic brain, liquid blood and clot was extruded. There were two tracks: one the missile track which was directed through the hemisphere towards the frontal lobe and was transventricular; and the other, the track of the indriven bone, perpendicular to the first, which was also transventricular. From this track a large single bone fragment was removed from just beneath the falx in the midline.

Figure 16.

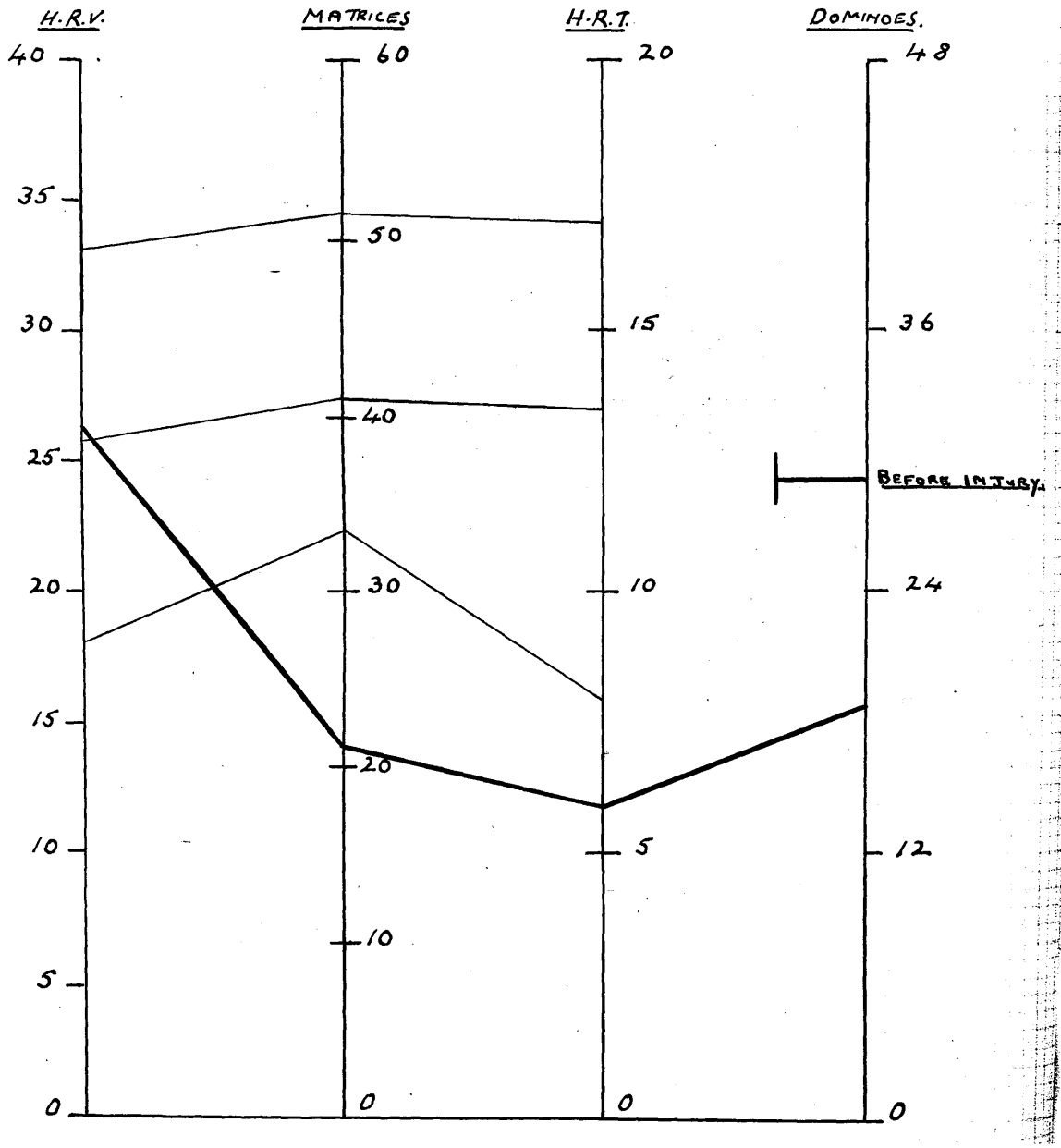

H.R.V.
MATRICES
H.R.T.
DOMINOES.
40
35
30
25
20
15
10
5
0
60
50
40
30
20
10
0
20
15
10
5
0
48
36
24
12
0
BEFORE INJURY.

Figure 15.

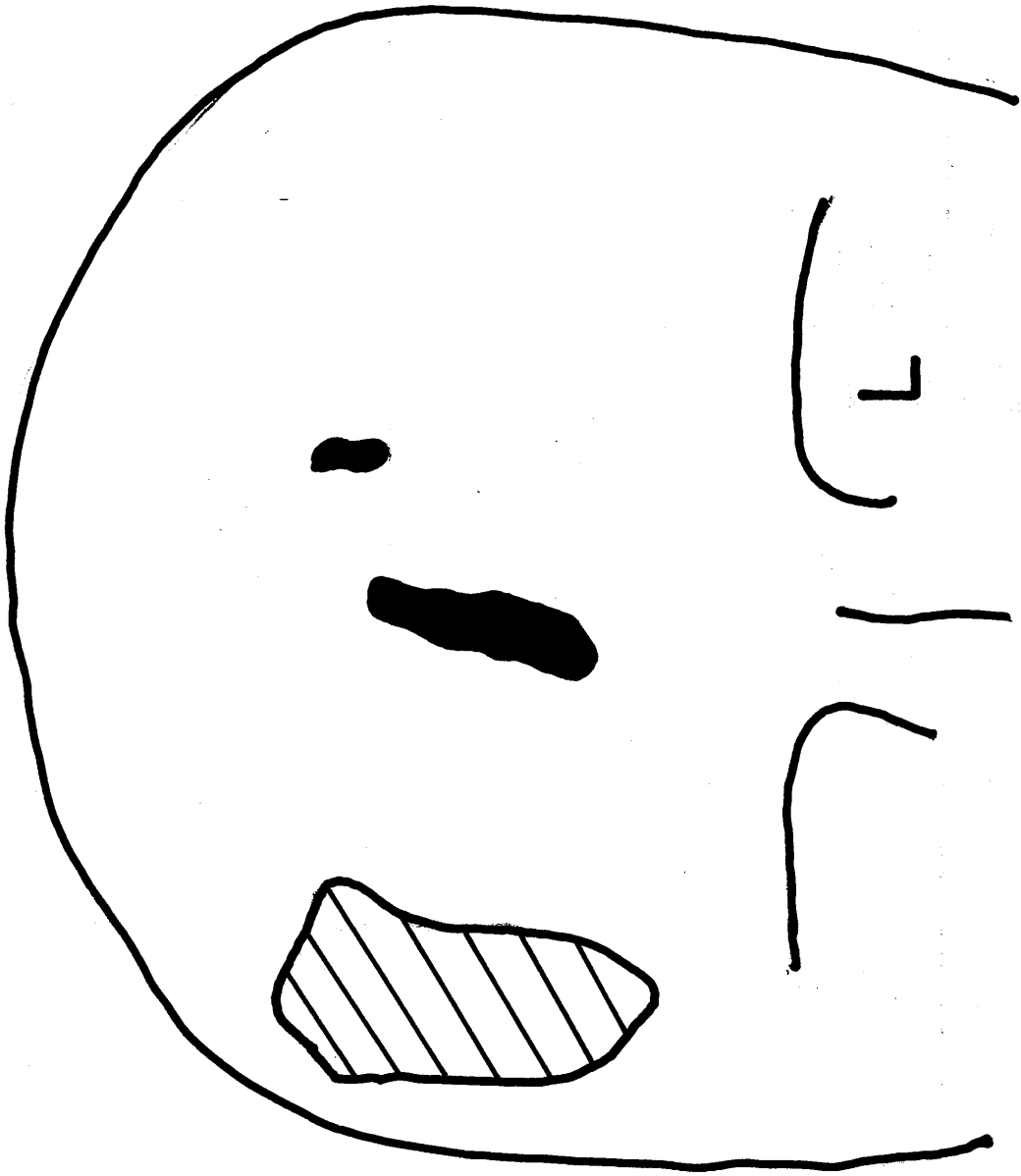
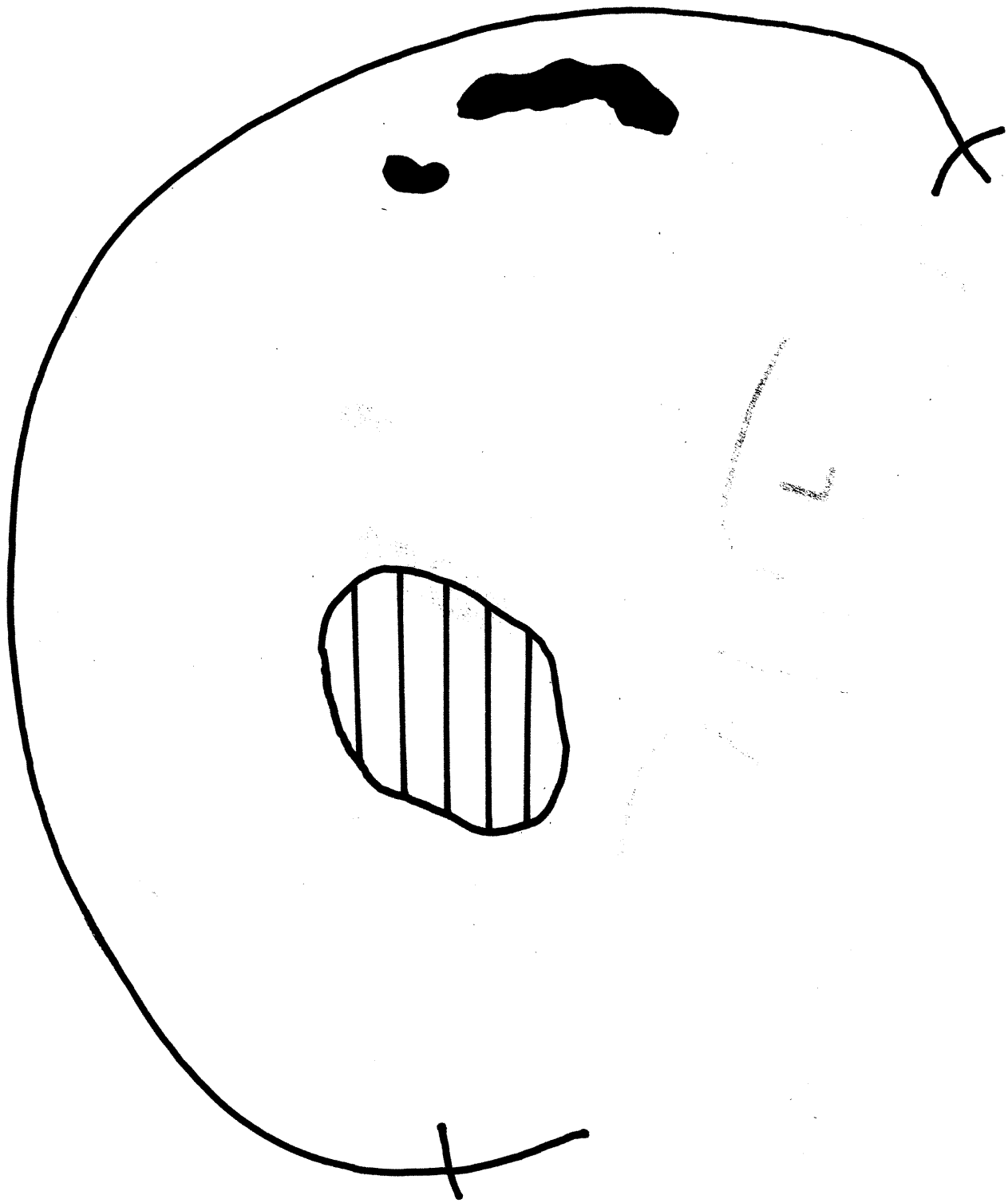


Figure 15.



Postoperatively the pupils began to react slightly, but the general picture was unchanged.

On 19th April the right pupil was still larger than the left, but both reacted well to light. Skull films showed a 3 x 5 cm. surgical defect in the right mid-parietal region. A large, thin, ragged piece of metal measuring 3 cm. in length lay in the midline of the frontal region, just beneath the inner table of the skull. There was a smaller fragment in the left frontal area 2 cm. from the midline and 2 cm. from the skull wall. There were no retained bone fragments (Fig. 15).

By 28th April he was beginning to move his right arm, but was still semi-conscious. By 5th May his consciousness had improved remarkably and he began to talk. He began to walk with help. By 7th May he was much clearer mentally and had a bilateral 3rd nerve palsy, but both pupils were equal and reacted to light.

He was admitted to the Military Hospital for Head Injuries on 10th June, 1953. He was left-handed. He felt well, but had marked double vision. His speech was slow and monotonous, but there was no dysphasia. He was fully orientated, and his memory for past events was fair. He remembered the whistle of the shell before he was hit, nothing more until 3 or 4 weeks later (R.A. a few seconds; P.T.A. 4 weeks). There was a bilateral hyposmia, and the visual fields showed a lower left quandrantanopia. Eyes were widely divergent, with conjugate deviation to the left, but with great limitation of other movements. There was bilateral facial weakness which was gross on the left. All four limbs were weak, with increased tone, the left more than the right, and the upper limbs more than the lower. A grasp reflex was present in the left hand. There was diminished two-point sensibility and astereognosis in the left hand, but no sensory change to pin-prick and cotton-wool. There was no spatial disorientation.

While in hospital he had an attack in which he suddenly fell to the ground with loss of consciousness and general convulsions.

Intelligence testing was carried out on 6th July, 1953, three months after injury. His approach to testing was good, and his scores were: H.R.V. 26, Matrices 21, H.R.T. 6, and Dominoes 19 (Fig. 16). His score on the Dominoes Test (19) was well below that which he had produced on Army entry 2 years previously (29).

His present score on the Matrices placed him in S.G. V and on the Dominoes in S.G. IV. His score on the Dominoes on Army entry in July, 1951, placed him in S.G. III+. His

scores on the battery of tests (Dominoes, proverbs, arithmetic, verbal, etc.) then administered also gave him an overall S.G. of III+. He was regarded as average in education and intelligence. He left school at 15 and before joining the Army was a labourer in a saw-mill.

In view of the fact that mental testing was carried out only 3 months after injury, it was repeated on 28th October, 1953. He appeared rather more alert than on the first occasion and now indulged in spontaneous talk. His scores on the tests, however, showed no appreciable change: H.R.V. 27, Matrices 19, H.R.T. 9, Dominoes 20.

When the nature of the injury is considered it can be seen that, anatomically, these 7 cases fall into 2 groups:

(a) consists of 3 cases (1, 8 and 56) in which the missile has produced an extensive destruction by passing completely, or almost completely, through and through, between the frontal and parietal areas.

(b) consists of 4 cases (5, 12, 17 and 31) in which the missile has penetrated deeply, either laterally inwards or vertically downwards, in 3 cases into the posterior frontal region (5, 12 and 17), and in one case (31) into the anterior parietal region.

Certain relevant features of these 7 cases are summarised in Table I.

TABLE I. CERTAIN ANATOMICAL AND NEUROLOGICAL FEATURES IN 7 CASES SHOWING AN UNEQUIVOCAL DEFICIT TO PROBLEM-SOLVING TESTS.

Case No.	Site & Direction of Wound	Depth (cm.)	R.A.	P.T.A. (days)	Hand-edness	Traumatic Epilepsy	Neurological Signs
Group (a).							
1	L. parietal to R. frontal	T & T	Few mins.	21	R.	+	L. hemiplegia including face
8	R. frontal to R. parietal	T & T	13hrs	21	R.	+	L. hemiplegia; L. cortical sensory loss
56	R. parietal to R. & L. frontal	T & T (incomplete)	Few secs.	28	L.	+	Bilat. 3 N. palsy; lower L. quadrantanopia. Bilat. facial weakness, L. side gross. wkness, incr. tone all 4 limbs L>R, upper > lower. Cortical sensory loss & astereognosis L hand. Early grasp refl. L hand
Group (b).							
5	R. post. frontal (vertically downwards	4	0	0	L pre-(dom. R. for writing by practice	0	L. facial wkness L-sided hypotonia (slight)
12	R. post. frontal (laterally inwards	6.5	Few secs	5	R. (L-footed)	+	Early expressive dysphasia w. occ. difficy. persisting. L-sided wkness arm +, hand ++ cort. sensory loss L. arm; astereognosis L. hand

TABLE I Group (b) (cont.).

Case No.	Site & Direction of Wound	Depth (cm.)	R.A.	P.T.A. (days)	Hand-edness	Traumatic Epilepsy	Neurological Signs
17	L.posterior Frontal (laterally inwards)	5	-	-	R.	0	Early expressive dysphasia w. occasional difficulty in word-finding persisting. Weakness R. arm and hand
31	R.anterior parietal (laterall inwards)	5	0	0	R.	+	Complete L.hemianaesthesia. Astereognosis L. hand. L-sided weakness, arm +

Certain points must now be commented upon. The wounds in Group (a) are very severe; indeed, they form the most extensively destructive in the series. They must have caused a wide disruption of the fibres passing between the frontal and parietal areas.

The wounds in Group (b) are more localised but have, nevertheless, passed deeply into the hemisphere. In two cases (12 and 17) they have passed laterally into the posterior part of the pre-frontal area in the region of the middle frontal gyrus near the motor cortex, in each case causing an early (largely expressive) dysphasia, now persisting only as an occasional difficulty, and minimal motor

weakness, most marked in the arm and hand. In Case 5 the wound has passed vertically downwards into the posterior pre-frontal region causing a minimal hemiparesis, and in Case 31 it has passed into the anterior parietal region, causing severe cortical sensory loss and motor weakness, again marked in the arm.

These wounds must in every case have entered deeply into areas where the white fibres of the long association tracts (especially those of the superior longitudinal fasciculus) are concentrated in their passage between the frontal and occipital poles, at least if the diagrams in anatomical text-books may be taken as a guide (Ranson, 1939; Mitchell, 1953).

As has been pointed out (Meyer et al., 1947), comparatively little attention has been paid in recent years to the anatomical and pathological aspects of the long association tracts, and they quote Bechterew (1899) as saying that after destruction of the frontal cortex of experimental animals degeneration can readily be demonstrated in the superior longitudinal fasciculus. Mettler (1935), [illegible] describes the superior longitudinal fasciculus as poorly organised in the macaque but believes its origin lies in the middle and inferior frontal gyri; some of its fibres degenerated following pre-frontal lesions in this animal.

Part of the difficulty in interpreting these results

lies in the fact that when degeneration is found in these tracts it is seldom traceable along their entire length, and this has thrown doubt on whether the long association tracts contain long association fibres at all. It seems reasonably certain, however, from work using the method of physiological neuronography in monkeys and apes (Bailey et al., 1943, 1944), that connections exist between Area 8 (Brodmann) of the pre-frontal cortex and Area 18 of the occipital lobe, and impulses travel presumably along the superior longitudinal fasciculus (Meyer et al., 1947).

The position with regard to the long association tracts in man is even less well-defined. In most anatomical text-books a fronto-occipital fasciculus is described in relation to the superior longitudinal fasciculus but lying on a deeper plane; but the ultimate connections of these tracts and the arrangement of the fibres within them is still problematical. In their human leucotomy material (in a cut normally entering the white matter through cortical areas 45 and 46) Meyer and his collaborators (1947) could find no evidence of degeneration in the superior longitudinal fasciculus and only suggestive degeneration of some fronto-occipital long association fibres.

In the absence of anatomical and physiological enlightenment, and with the lack, as yet, of objective pathological evidence of the exact destruction caused by these wounds, further speculation must be valueless.

Nevertheless, it seems clear that the serious interference with the fibres of these tracts which must have resulted from these 7 wounds is an important factor in reducing the capacity of the subject to perform problem-solving tests.

The unilateral nature of the wound in some of the cases should be observed, and while no relation with cerebral dominance can be seen the preservation of the functional autonomy of speech (shown strikingly in Cases 1 and 8), in spite of the diminished capacity to solve problems, should be noted.

Group II - Cases without Demonstrable Deficit.

There are 38 cases in this group (Nos. 3, 4, 6, 7, 10, 13, 15, 18, 19, 23, 28, 34, 35, 37, 39, 40, 41, 42, 44, 45, 46, 47, 50, 52, 53, 54, 55, 58, 59, 60, 61, 63, 65, 66, 67, 68, 69 and 70).

When there was reasonable evidence, based on the test performance, that the subject was functioning within his normal intellectual range, then he was placed in the group showing "no deficit". Where the results of the intelligence testing before injury were available, and the actual scores had been obtained (and this invariably meant on the Dominoes Test), then the following criteria were used. Cases in which the Dominoes score had remained the same, had increased, or had fallen by not more than 3 points, were placed in the "no deficit" group. Cases in which the

Dominoes score had fallen by 4 or more points were placed in the "doubtful" group.

In 20 of the 38 cases pre-injury test results or selection grades were available. The results of testing before and after injury in these 20 cases are given in Table II.

TABLE II. RESULTS OF MENTAL TESTING BEFORE & AFTER INJURY IN 19 CASES IN WHICH NO INTELLECTUAL DEFICIT COULD BE DEMONSTRATED.

Case No.	Matrices Before Injury	Matrices After Injury	Dominoes Before Injury	Dominoes After Injury	Plus (+) Diffnce.	Minus (-) Diffnce.
3	S.G. I	S.G. II				
10		S.G.III	S.G.III+			
13			19	29	10	
18			23	32	9	
23			24	24		
28	S.G.III-	S.G. IV		S.G.III-		
35			34	37	3	
41			38	38		
42	S.G. IV	S.G.III+		S.G.III-		
44			S.G.II	S.G. II		
45			34	36	2	
47			32	31		1
50			26	35	9	
53			14	21	7	
55			24	29	5	
60			29	28		1

TABLE II (cont.).

Case	Matrices		Dominoes		Plus (+) Diffnce.	Minus (-) Diffnce.
	Before Injury	After Injury	Before Injury	After Injury		
63			23	28	5	
67			11	15	4	
69			22	24	2	
70			14	16	2	

The relevant anatomical and neurological details of these 38 cases will be presented mainly in a series of tables, but a few representative case histories will be given in greater detail.

Many of the Korean cases are being described within 2 years of injury, and the final position with regard to the development of traumatic epilepsy cannot yet be assessed (Russell & Whitty, 1952). Electroencephalographic findings are now reported briefly where available, but their significance should not be overestimated.

The 38 cases can be classified into 3 groups, according to the nature of the injury:

(a) Wounds penetrating the brain to a depth of less than 1 cm. (15 cases).

(b) Wounds penetrating the brain to a depth of more than 1 cm. and involving more than one cerebral area (3 cases).

(c) Wounds penetrating the brain to a depth of more

than 1 cm. but more or less restricted, unilaterally or bilaterally, to homologous cerebral areas (20 cases).

(a) Wounds penetrating the brain to a depth of less than 1cm.

A study of the details of the 15 cases in this group (Table III) will show that the majority of the wounds were of the superficial cortical type, usually due to a depressed fracture, caused by, but mostly without actual penetration of, a missile, and occasionally resulting in the depression of a few bone fragments into the brain. In some cases the dura had not been penetrated, but was incised at operation where an underlying area of brain softening or contusion was found.

In each case the position of the skull defect has been plotted on a normal skull outline by the method described by Russell (1947) and the centre of the skull defect is indicated by the case number (Fig. 17).

Figure 17.

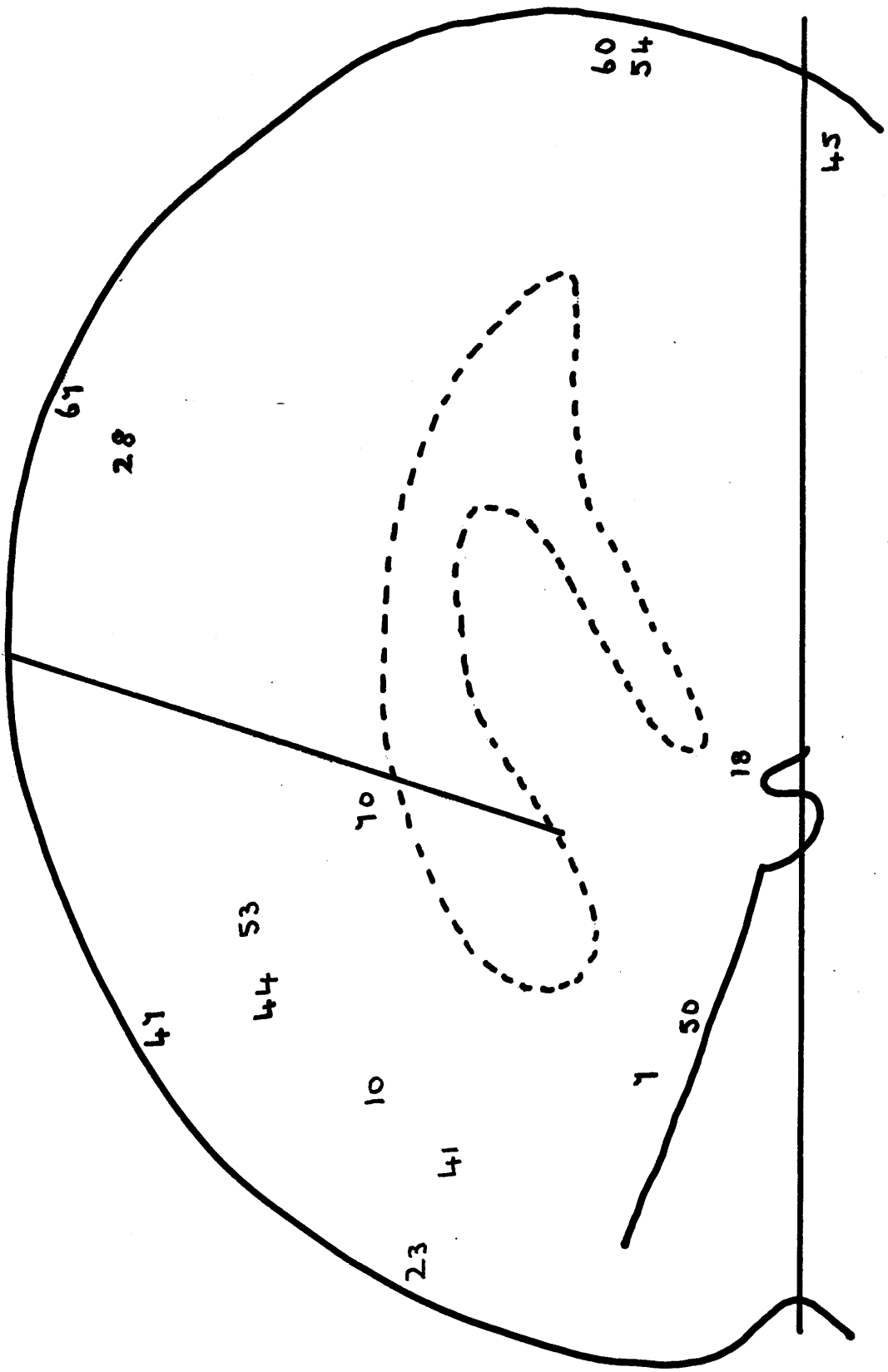


TABLE III. ANATOMICAL & NEUROLOGICAL DETAILS OF 15 CASES IN WHICH NO INTELLECTUAL DEFICIT COULD BE DEMONSTRATED AND WHERE THE WOUNDS HAVE PENETRATED THE BRAIN TO A DEPTH OF LESS THAN 1 cm.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	Site				Dura			Brain									
Case & Index No.	Hemisphere	Lobe	Fr.	Size of Skull Defect	Penetrated	Incis.at op.	Subd.Haem.	Softening	Bone frgmts	M.F.B.	R.A.	P.T.A. (days)	A.E.G.	E.E.G.	Traumatic Epilepsy	Neurological Signs	Other
7 (961)	L.	F.	Dep.	1 x 1.5 cm.	+	0	+	+	0	0	Few sec.	7	Normal	Paroxsmal activ. (?)	Dizzy attacks (?)	0	0
10 (964)	L.	F.	Dep.	4 x 4.5 cm.	+	0	+	+	+	0	5 min.	7	-	Paroxysmal activ. (?)	0	L. pupil larger than R. Proptosis & downward displacemt. L. eye; diplopia to R. R-sided wkness (sl). R. P.R. ↑ ?	L. Frontal sinus involved in fr.
18 (978)	L.	T.	Dep.	1 x 1 cm.	+	0	0	0	+	+	0	0	Normal	Normal	0	0	0
23 (980)	L.	F.	Dep.	2 x 3 cm.	0	+	+	+	0	0	10 min.	3	Normal	Paroxysmal activ. (?)	0	Early R. ext. pl. response & hyperactive reflexes R. leg	0
28 (982)	R.	P.	Dep.	2 x 1 cm.	+	0	0	0	0	0	0	0	Normal	Normal	0	0	0
41 (990)	L.	F.	Dep.	3 x 3 cm.*	+	0	0	+	+	0	Few hrs.	21	-	Normal	0	L. eye lower than R. & exophthalmic. Diplopia in all dir. to L. C.S.F. Rhinorrhoea (?)	L. frontal sinus involved in fracture

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
44 (991)	L.	F.	Lin.	1 x 1.5 cm *	0	+	0	+	0	0	Few sec.	28	Normal	Parox. focus mid-fr. (?)	0	0	(a) Pen. wnd. chest (b) "peppering" of scalp, numerous MFBs (c) ext. contusion surrounding area of brain softening (d) Severe confusional disorder in early wks. - disorientated; irritable; overactive; speaking & acting obscenely (masturbating openly); incontinent urine & faeces
45 (992)	L.	O.	Dep.	3 x 3 cm.*	+	0	0	+	+	0	Few sec.	3	-	Borderline	0	L-sided deafness. Early ataxia L. arm and leg	Early restlessness & confusion (mild)
47 (993)	L.	F.	Dep.	2 x 3 cm.*	+	0	0	+	+	0	Few sec.	Few min.	Dilatn. vent. system L > R Sl. tracn. body L. vent. towards wound	Borderline	0	0	0
50 (996)	L.	F-T	Dep.	4 x 3 cm.	0	+	0	+	0	0	Few sec.	3	-	Normal	0	0	(a) Destr. L. eye (sep. wnd.) (b) Cont. lat. surf. frontal lobe; softening tip temporal lobe (c) euphoria

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
53 (997)	L.	F.	Dep.	3 x 3.5 cm. *	+	0	0	+	+	0	0	0	Normal	Borderline	0	0	0
54 (405)	L.	O.	Dep.	0.5 x 0.5 cm	+	0	0	+	+	0	0	0	-	Borderline	0	Early R. hemianopia Residual lower R. quadrantanopia	0
60 (1000)	L.	O.	Dep.	1 x 2 cm.	0	+	0	0	0	0	0	0	-	Borderline	0	Early disturbance of vision. Residual lower R. quadrantanopia	Laceratn. sagittal sinus by MFBs & bone fragments
67 (994)	R.	P.	Dep.	4 x 4 cm. *	0	+	+	+	0	0	Few sec.	Few min.	Irreg. post. part bdy R. vent.	Parox. activ. R. parietal (?)	Attacks numbness L. foot (?)	Disturbance of joint sense toes L. foot	Early confusion
70 (1006)	R.	F.	Dep.	1 x 0.5 cm	0	+	0	+	0	0	0	0	Normal	Parox. activ. R. frontal (?)	Dizzy attacks (?)	0	0

*In these cases the size of the skull defect is that remaining after operation.

F.= Frontal O.= Occipital T.= Temporal F-T.= Fronto-temporal P.= Parietal Lin.= Linear Dep.= Depressed

(b) Wounds penetrating the brain to a depth of more than 1 cm. and involving more than one cerebral area.

A study of the 3 cases in this group (Table IV) will show that the wound in each case has been caused by a small metal fragment passing through one cerebral area to its resting-place in another. The missile tracks, with the final position of the metallic fragments, have been represented diagrammatically on a normal skull outline (Fig. 18).

Figure 18.

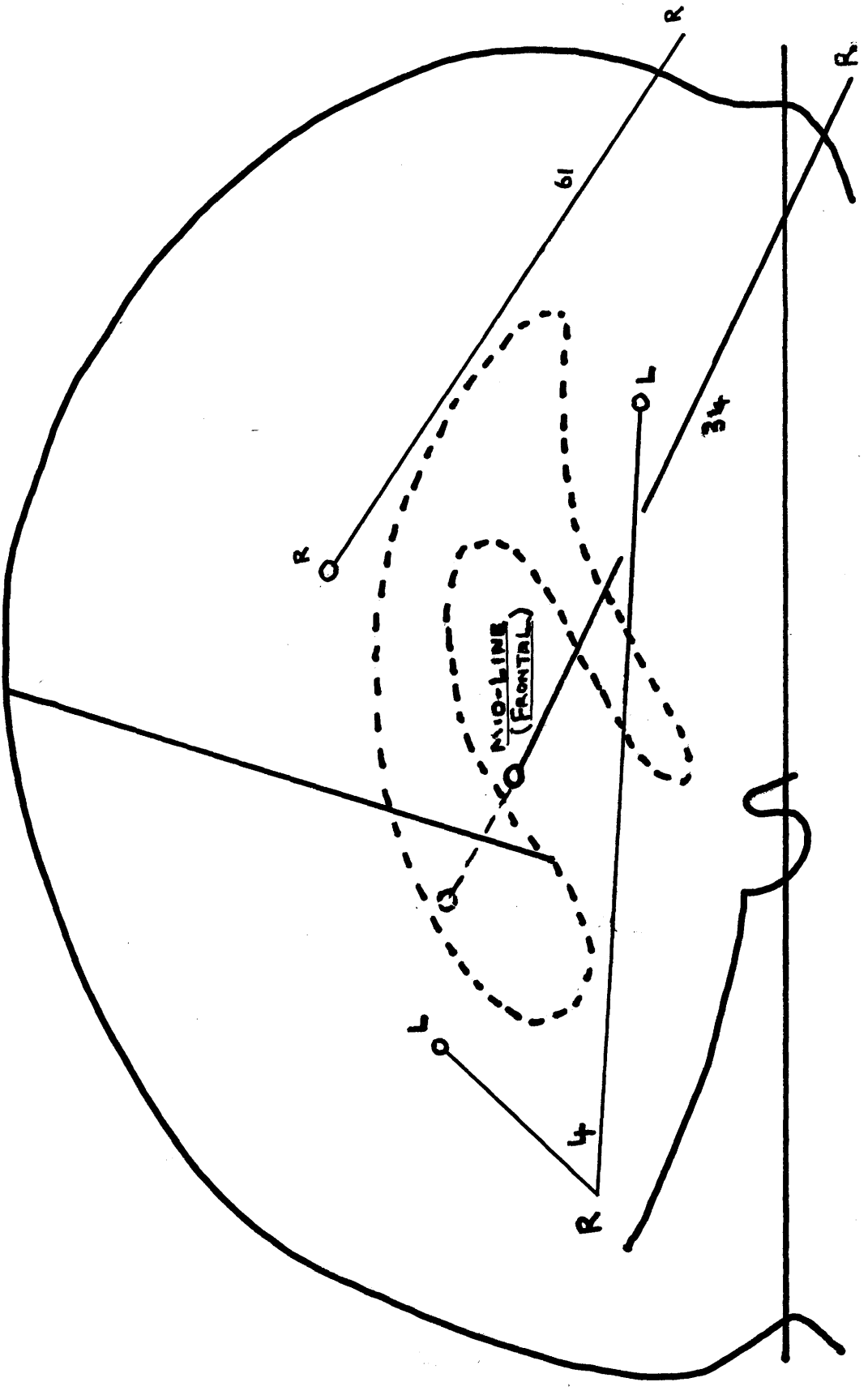


TABLE IV. ANATOMICAL & NEUROLOGICAL DETAILS IN 3 CASES IN WHICH NO INTELLECTUAL DEFICIT COULD BE DEMONSTRATED & WHERE THE WOUNDS HAVE PENETRATED THE BRAIN TO A DEPTH OF MORE THAN 1 cm. & HAVE INVOLVED MORE THAN ONE CEREBRAL AREA.

Case & Index Nos.	Direction of Missile From	Track To	MFBs Retained	R.A.	P.T.A. (days)	A.E.G.	E.E.G.	Traumatic Epilepsy	Neurological Signs	Other
4 (968)	R. Front.	L.Front. & L. Pariet.	2	Few secs.	3	Symmetrical	General dysrhythmia (4-6 c/s activ.) suggesting deep central damage	0	Early L. hemiparesis (sl.), with hyperactive tendon reflexes	Early confusion; now reports occ. dysphasic difficulty & mixing sentences
34 (455)	Rt. Occip.	Mid-front.	1	Weeks	Mths.	System central; sl. gen. frontal enlargemt. w. MFBs betw. ant. horns	Grossly abnormal	+	L. upper quantranopia	Gross confusion, disorientation & confabulation in early mths. after injury (traumatic Korsakow syndrome)
61 (989)	R. Occip.	R. Pariet.	1	0	1	Sl. displacemt. of syst. to R. No dilatation	Grossly abnormal	+	L. homonymous hemianopia. Minimal weakness L. hand	

(c) Wounds penetrating the brain to a depth of more than 1 cm. but more or less restricted, unilaterally or bilaterally, to homologous cerebral areas.

There are 20 cases in this group. Many of the wounds were severe and in 16 cases were restricted to the frontal lobes. The distribution of the 20 cases among different cerebral sites is given in Table V.

TABLE V. DISTRIBUTION OF 20 CASES RESTRICTED TO HOMOLOGOUS CEREBRAL AREAS.

Cerebral Area	Unilateral		Bilateral
	R.	L.	
Frontal	5	4	7
Parietal	1	2	-
Temporal	-	1	-

The details of these cases and the references to the figures illustrating them are given in Table VI. Four of the cases indicated only by their case numbers in Table VI are later described in greater detail.

Figure 20.

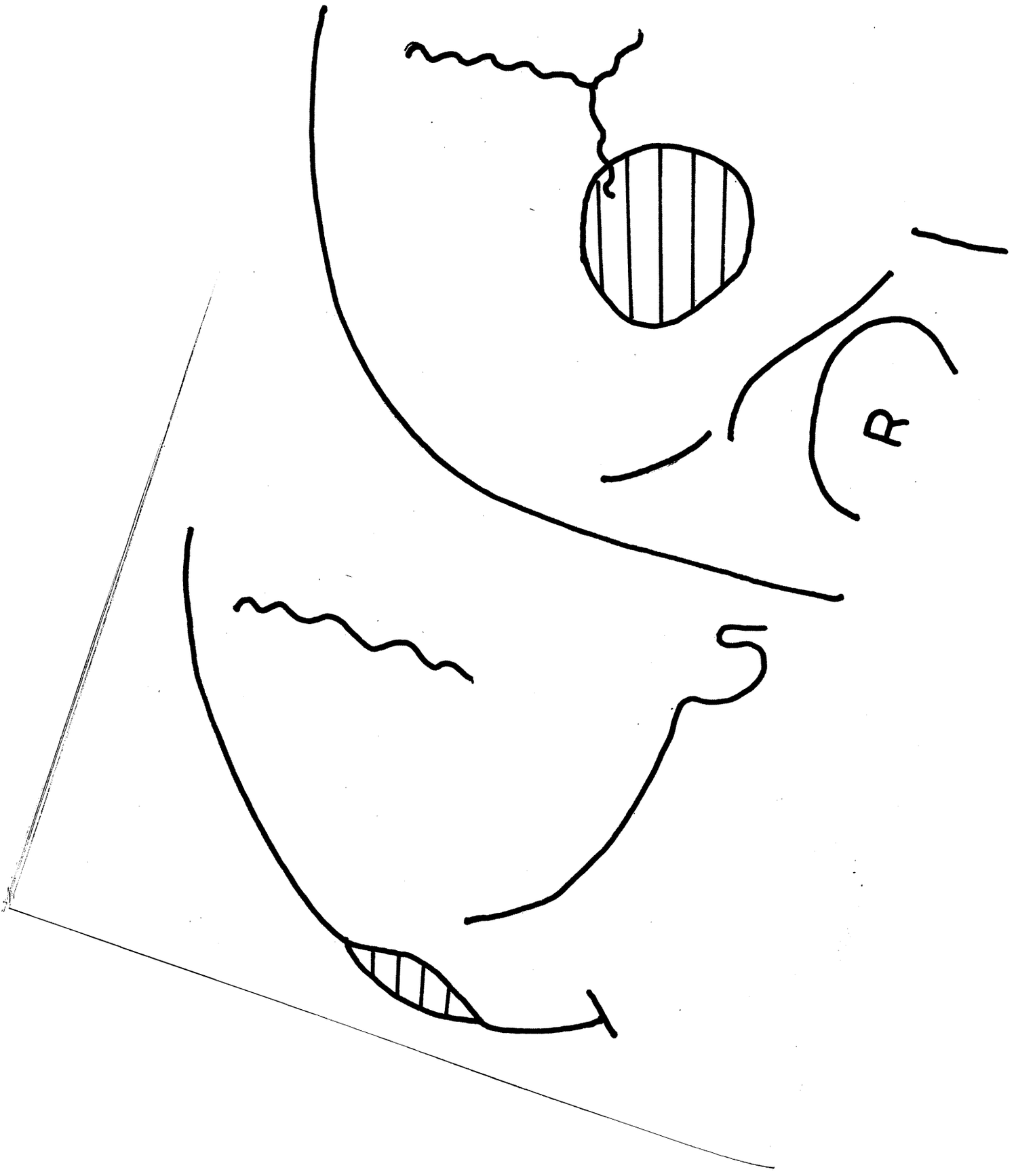


Figure 19.

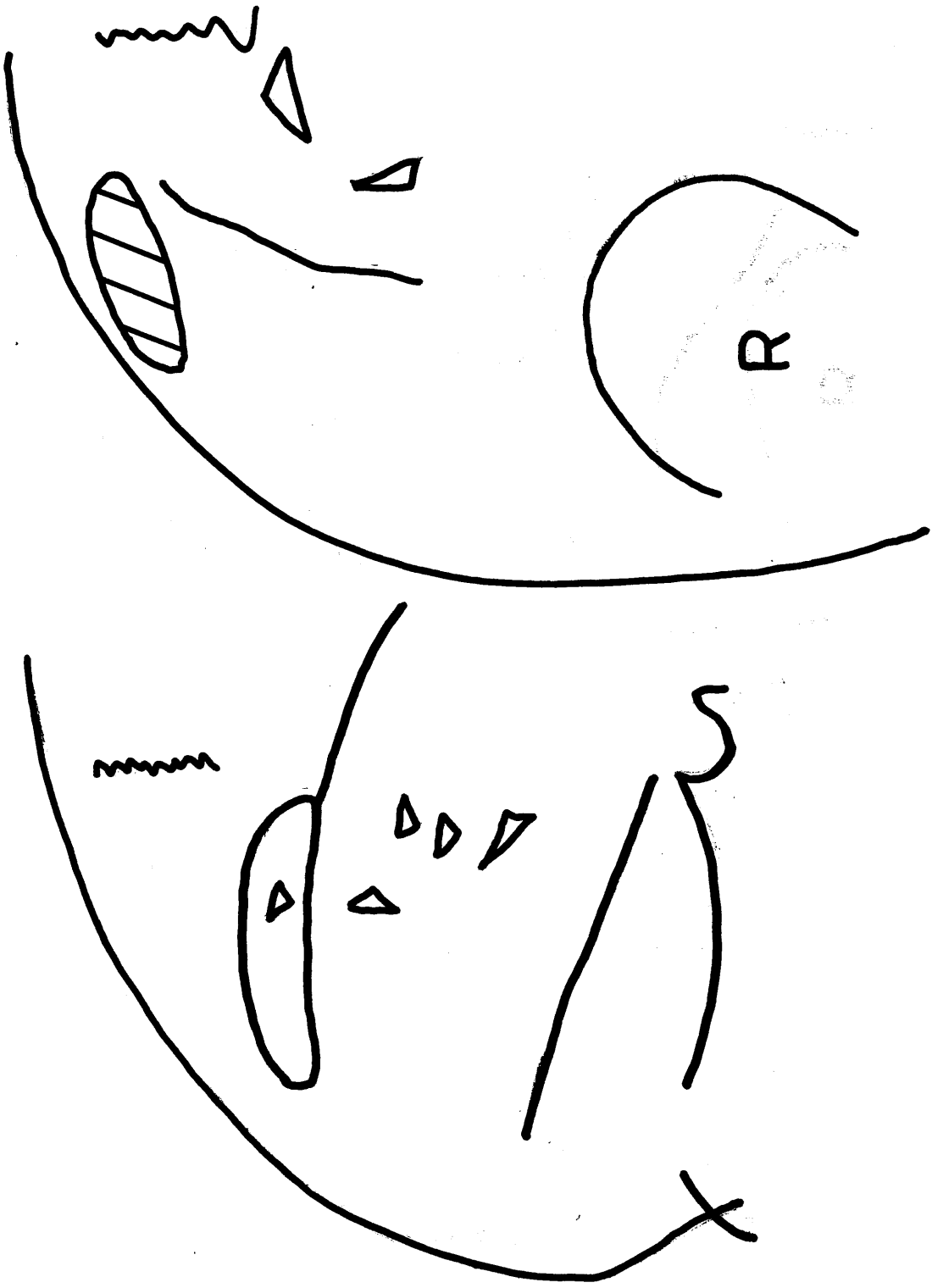


TABLE VI. ANATOMICAL & NEUROLOGICAL DETAILS IN 20 CASES IN WHICH NO INTELLECTUAL DEFICIT COULD BE DEMONSTRATED & WHERE THE WOUNDS HAVE PENETRATED THE BRAIN TO A DEPTH OF MORE THAN 1 cm. BUT ARE RESTRICTED TO HOMOLOGOUS CEREBRAL AREAS.

1	2	3	4	5	6	7	8
Case & Index No.	Details of Wound	R.A.	P.T.A. (days)	A.E.G.	E.E.G.	Traumatic Epilepsy	Neurological Signs
FRONTAL UNILATERAL RIGHT (5)							
39 (741)	Entry parasagittal, two tracks: 1. Forwards & medially entering lat. ventricle; 3 tiny MFBs & 8 bone fragments removed. 2. Small track, laterally & backwrds; 1 MFB removed. Indriven bone fragments remain in post-operative X-rays (Fig. 19)	Few mins.	5	-	Abnormal	+	L. facial paresis. Weakness L. arm and hand
40 (406)	Entry supraorbital near midline. Minute penetration of dura, but lacerated brain & clot removed from a track passing backwards & slightly laterally to a depth of 4 cm. (Fig. 20)	0	0	-	Mild focal abnormly. R. frontal	+	0
52 (416)	Entry supraorbital. Bone fragments & 1 MFB (1 x 1 x 1 cm.) indriven to depth of 7 cm. (removed at operation). Brain abscess developed subsequently. (No X-rays available)	Few secs.	3	Porencephalic enlargemt. R. ant. horn w. syst. sl. displaced to R. anteriorly	Focal dysrhythmia R. frontal	Dizzy attacks (?)	Early L. facial weakness

Figure 24.

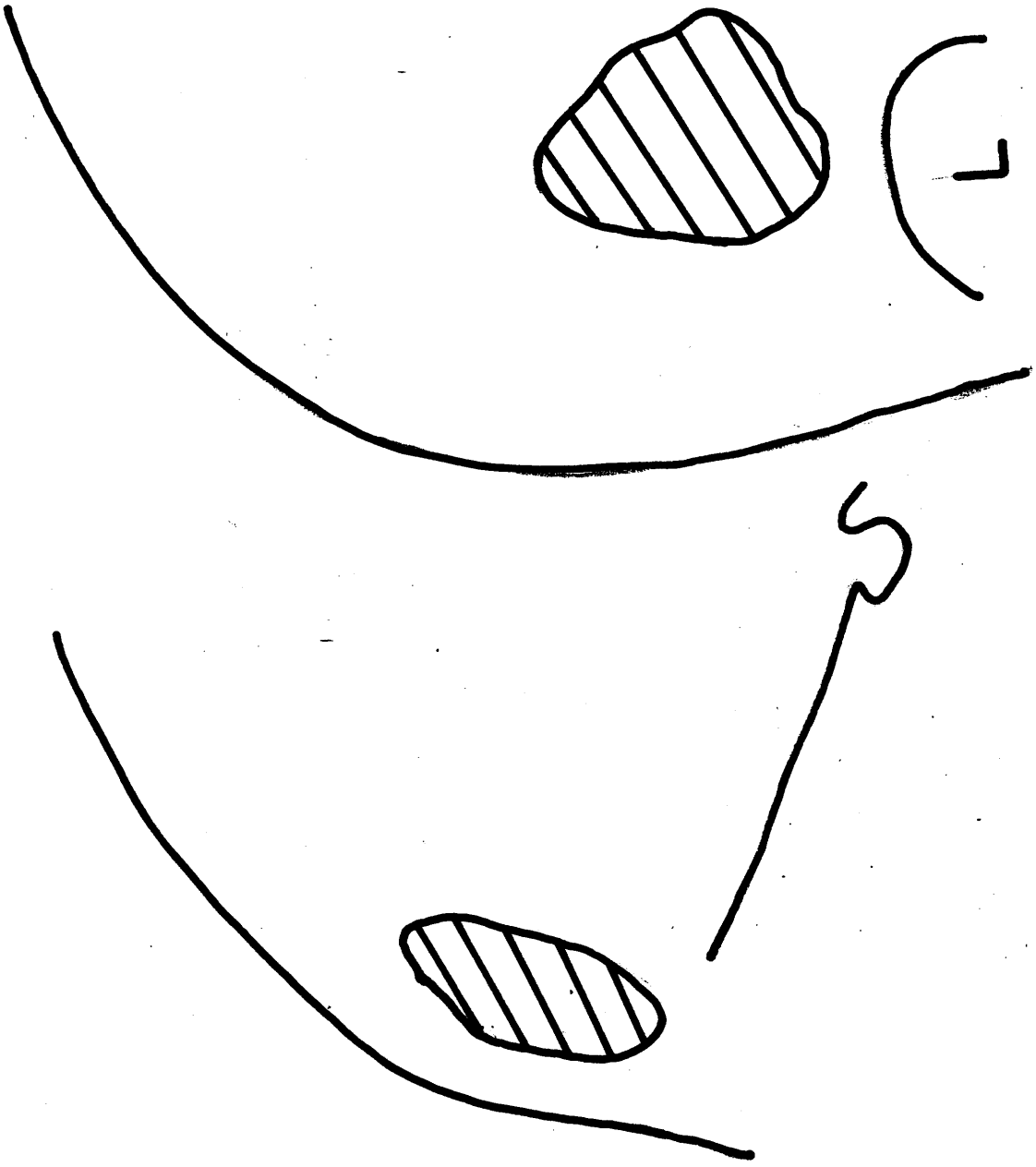


Figure 25.

Figure 22.

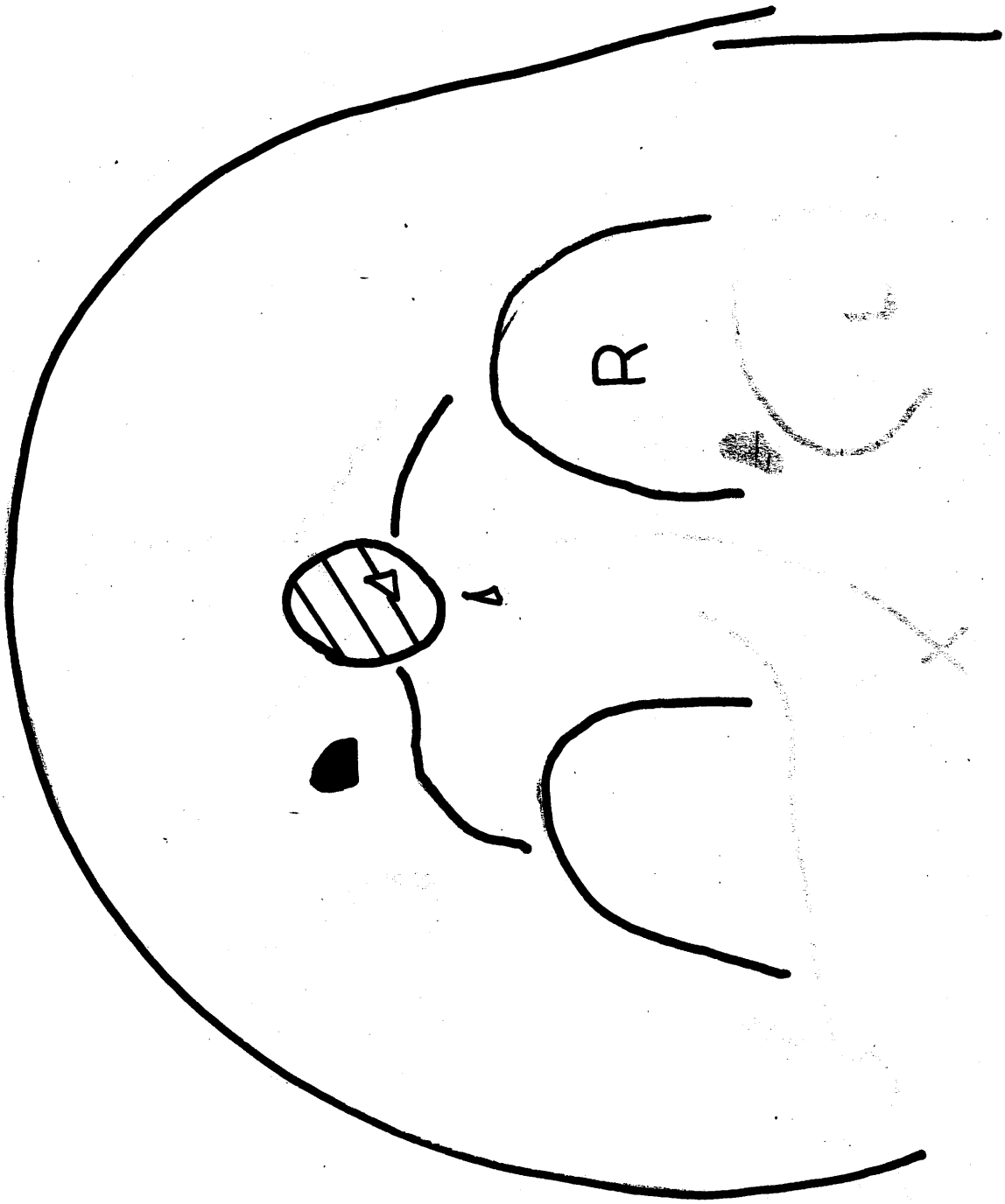
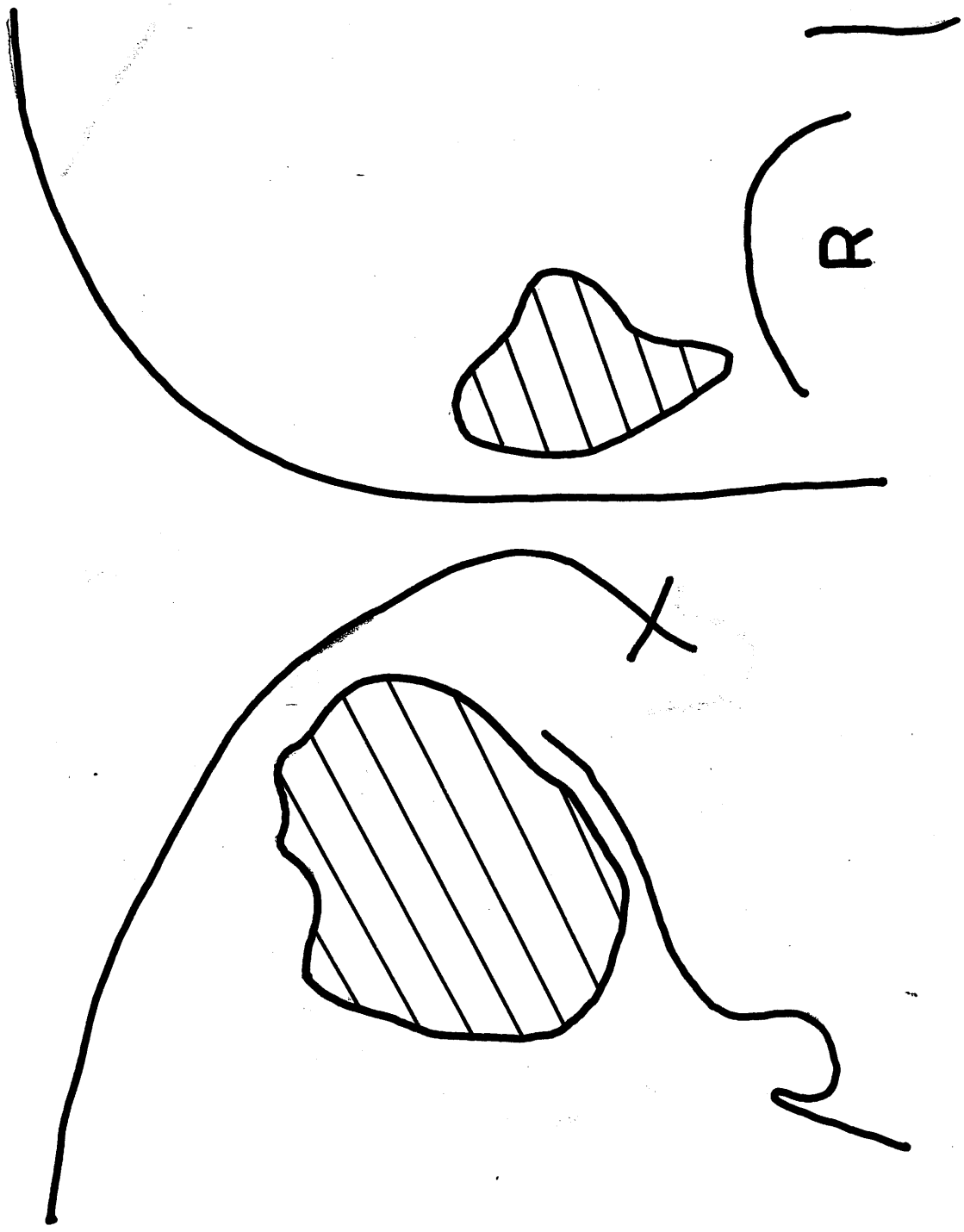


Figure 22.

Figure 21.



1	2	3	4	5	6	7	8
55	SEE TEXT						
63 (1002)	Entry supraorbital. Bone fragments indriven to depth of 6 cm. through a hole in the frontal bone & supraorbital ridge measuring 6 x 4 cm. Bone fragments & liquefied brain removed at operation (Fig. 21)	1 day	7	Sl. dilatation R. ant. horn; displacement ant. part of syst. towards defect	Occ. asynchronous spikes	0	Early confusion & disorientation. R. pupil dilated & fixed; spastic hemiparesis L. arm. R. central chorioretinitis w. only small patch of vision remaining in temp. field R. side
FRONTAL UNILATERAL LEFT (4)							
35	SEE TEXT						
46 (926)	Entry supraorbital near midline. Several MFBs deep in L. frontal lobe. (Fig. 22)	Few secs.	5 min.	No gross deformty. or displacemt.	Paroxysmal activ.	+	L. eye destroyed. Fracture involves upper margin of frontal sinuses. No neurological signs
65 (O.S. 2037)	Entry parasagittal. At operation a probe passed down the track to a depth of 7 cm. Post-op. X-ray shows 3 fair-sized bone fragmts. indriven to a depth of 2 cm. downwards & inwards, & a MFB wh. has passed almost directly downward & lies 1 cm. above & to the L. of the ant. clinoid process (Fig. 23)	0	7	Dilatatn. of both anterior horns	Abnormal	+	0
69 (1005)	Entry supraorbital. Bone fragmts. indriven deeply into frontal lobe thro' penetration of dura 2 x 1 cm. track entering ventricle. Fragmts. & necrotic brain removed at op. (Fig. 24)	Few secs.	3	-	No paroxysmal activty.	0	Early confusion & restlessness. No neurological signs

Figure 28.

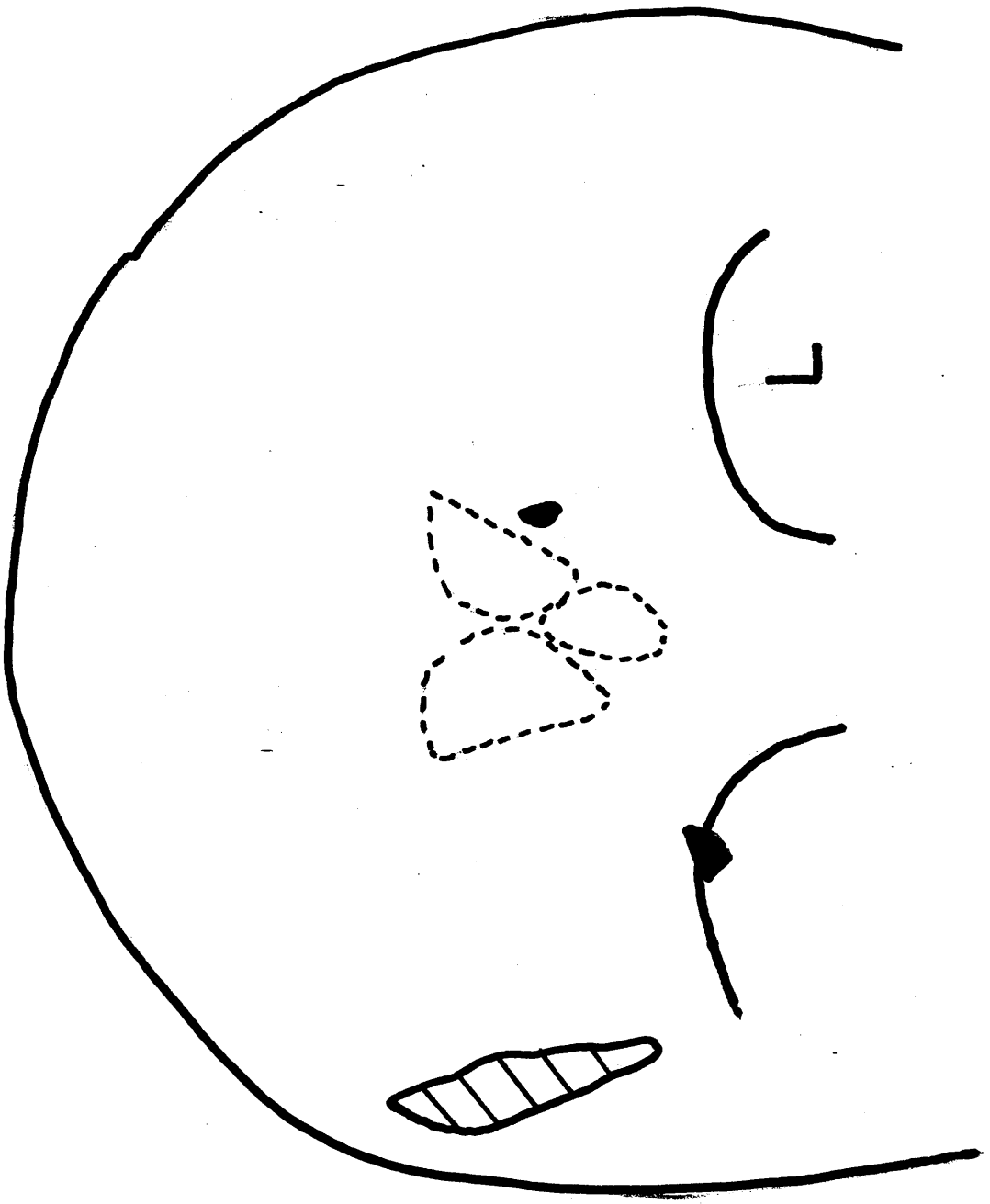


Figure 28.

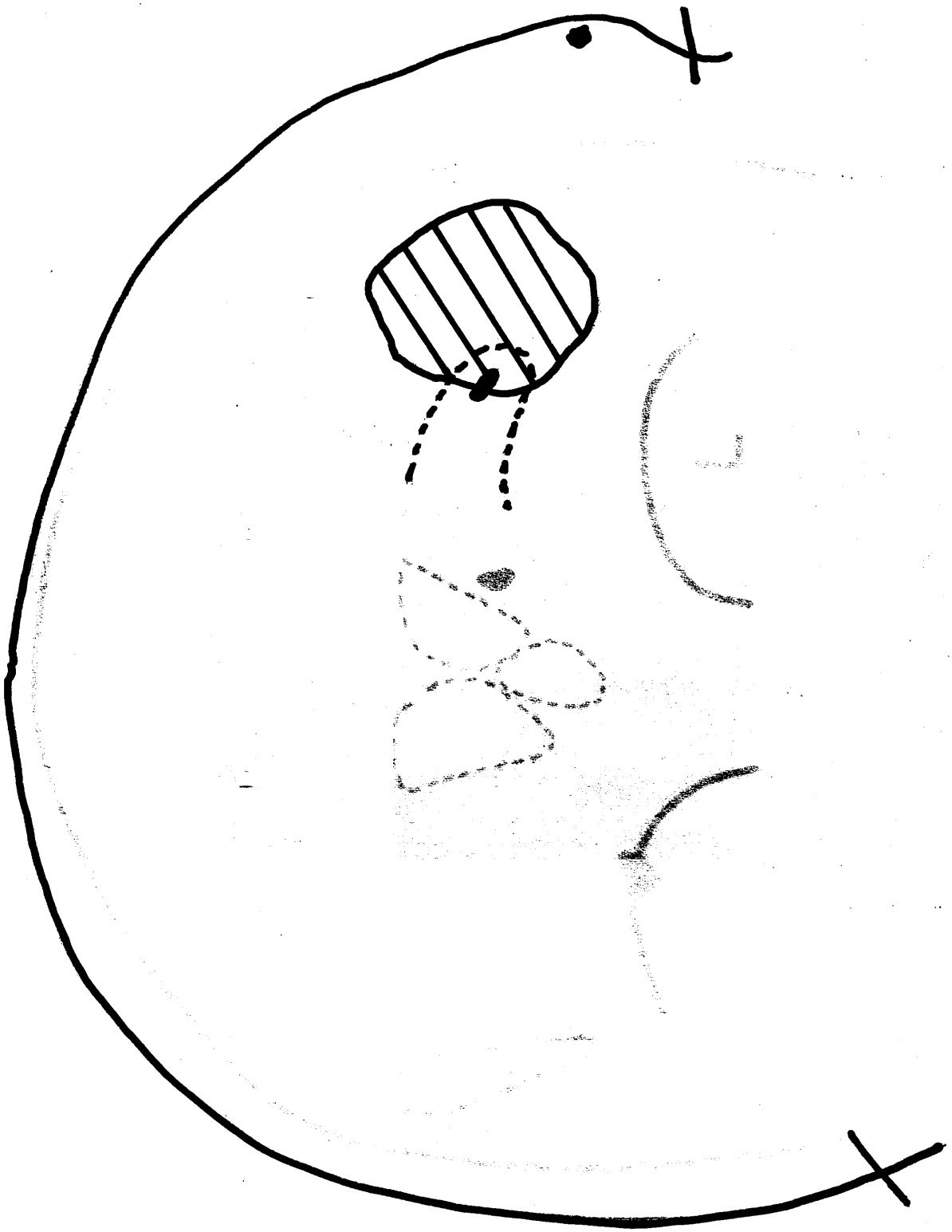


Figure 27.

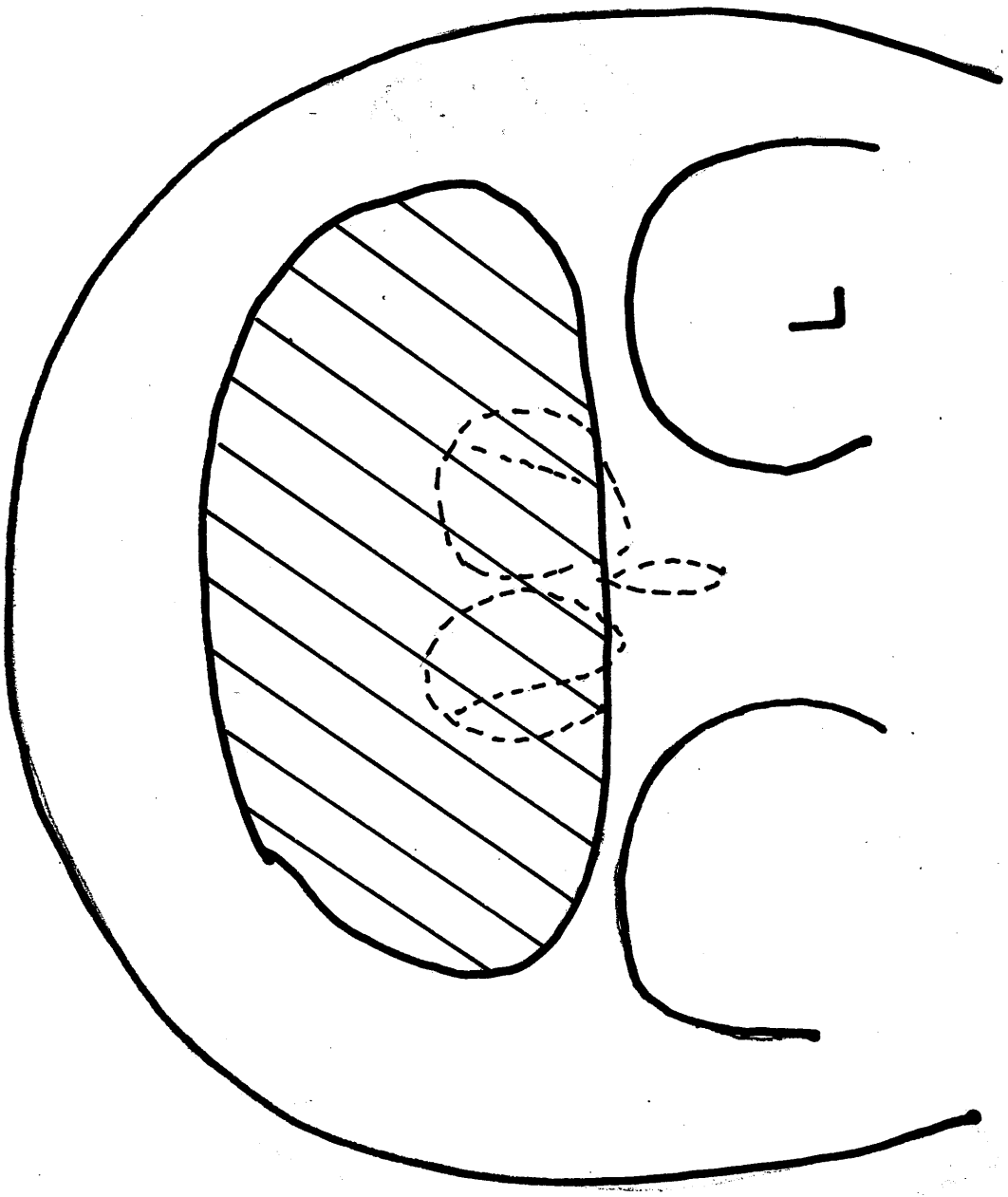


Figure 27.

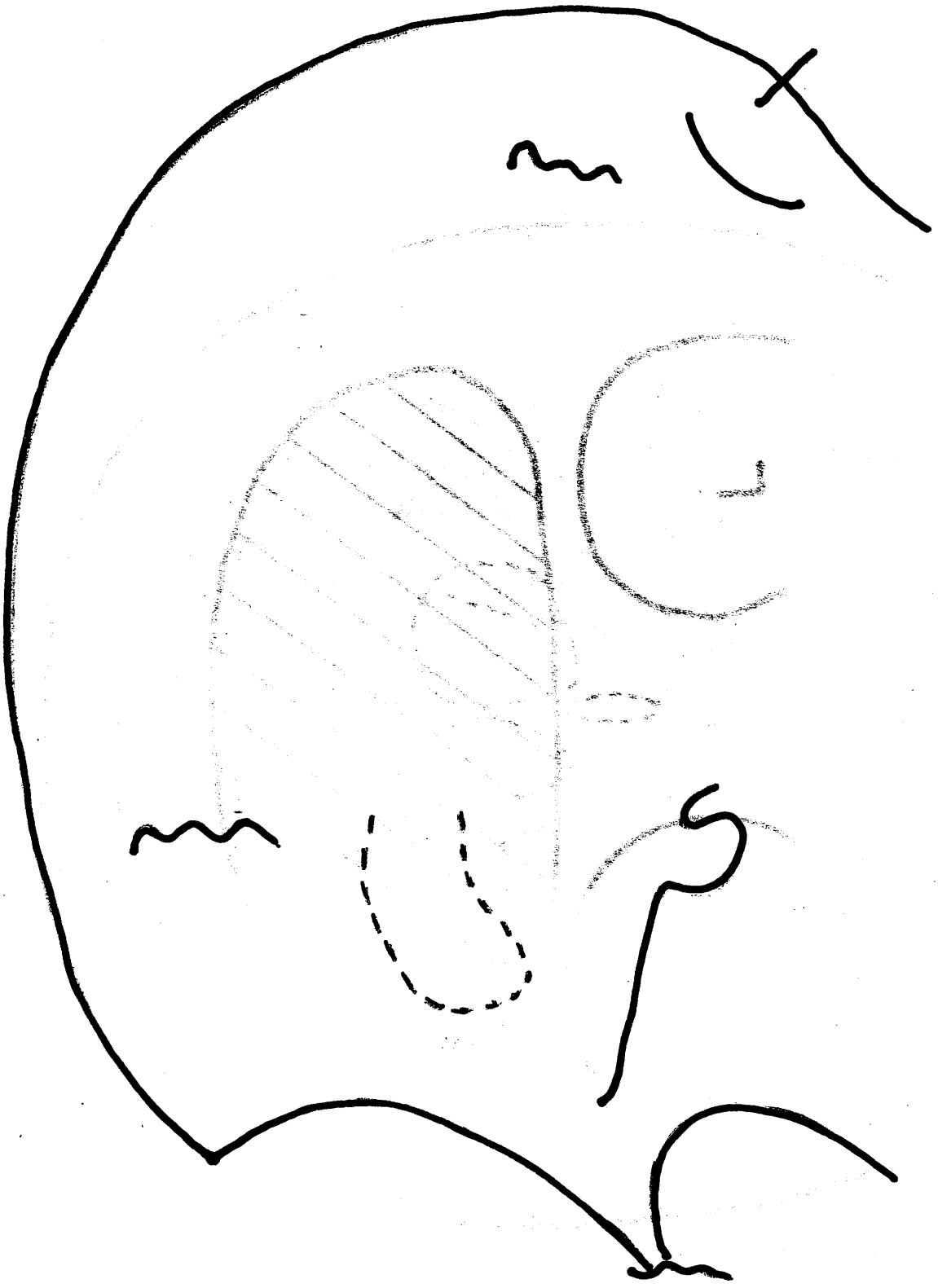


Figure 26.

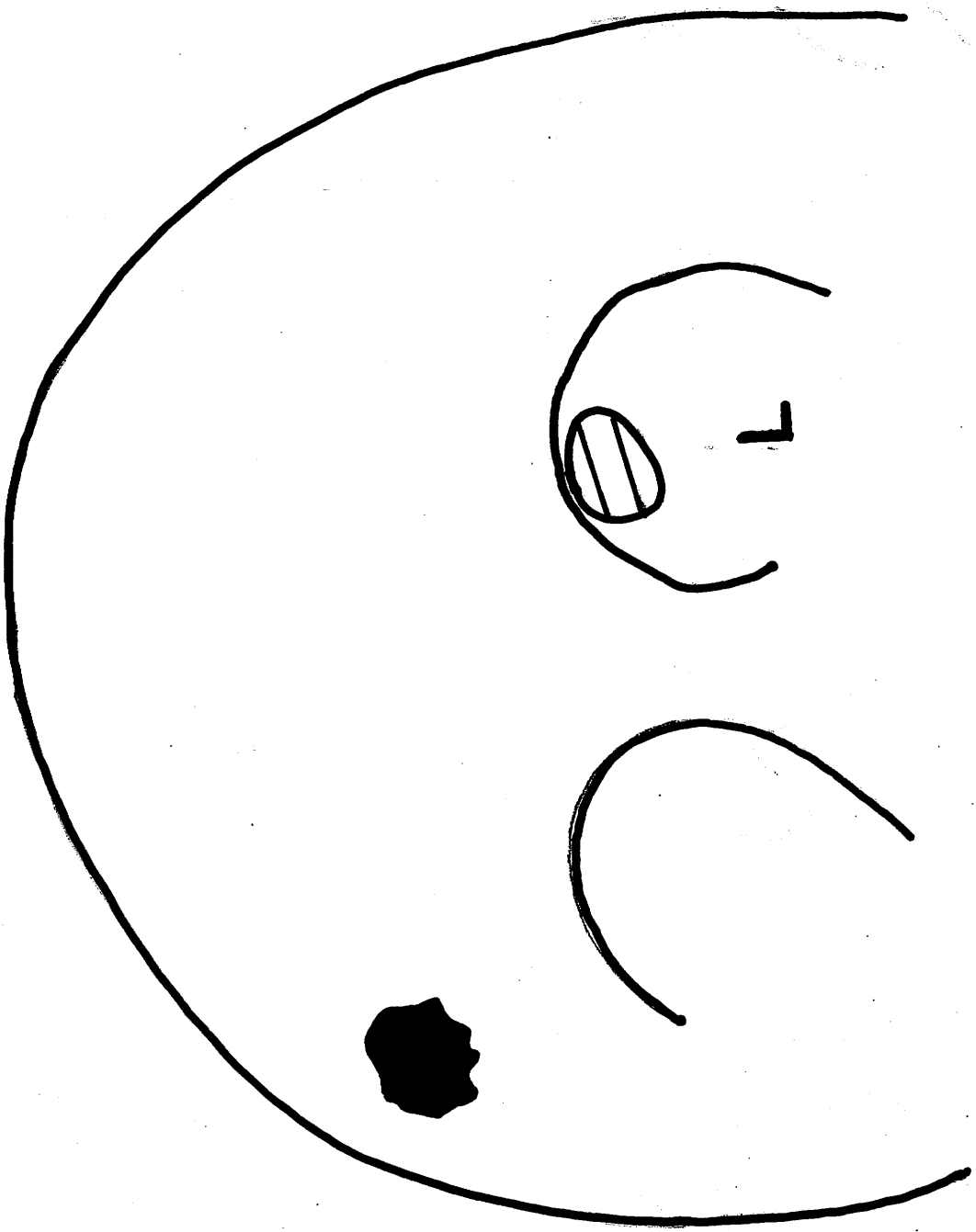


Figure 26.

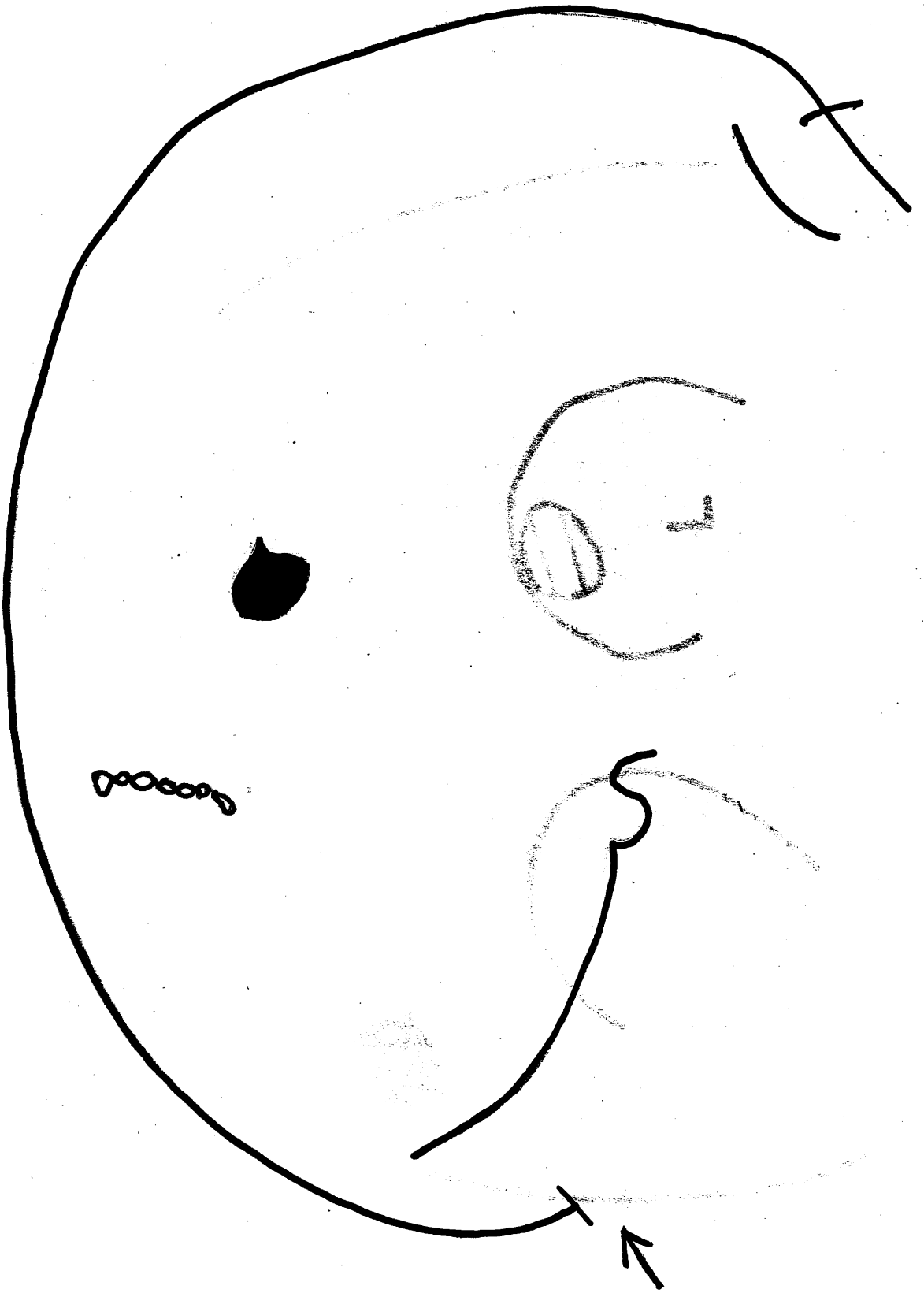


Figure 25.

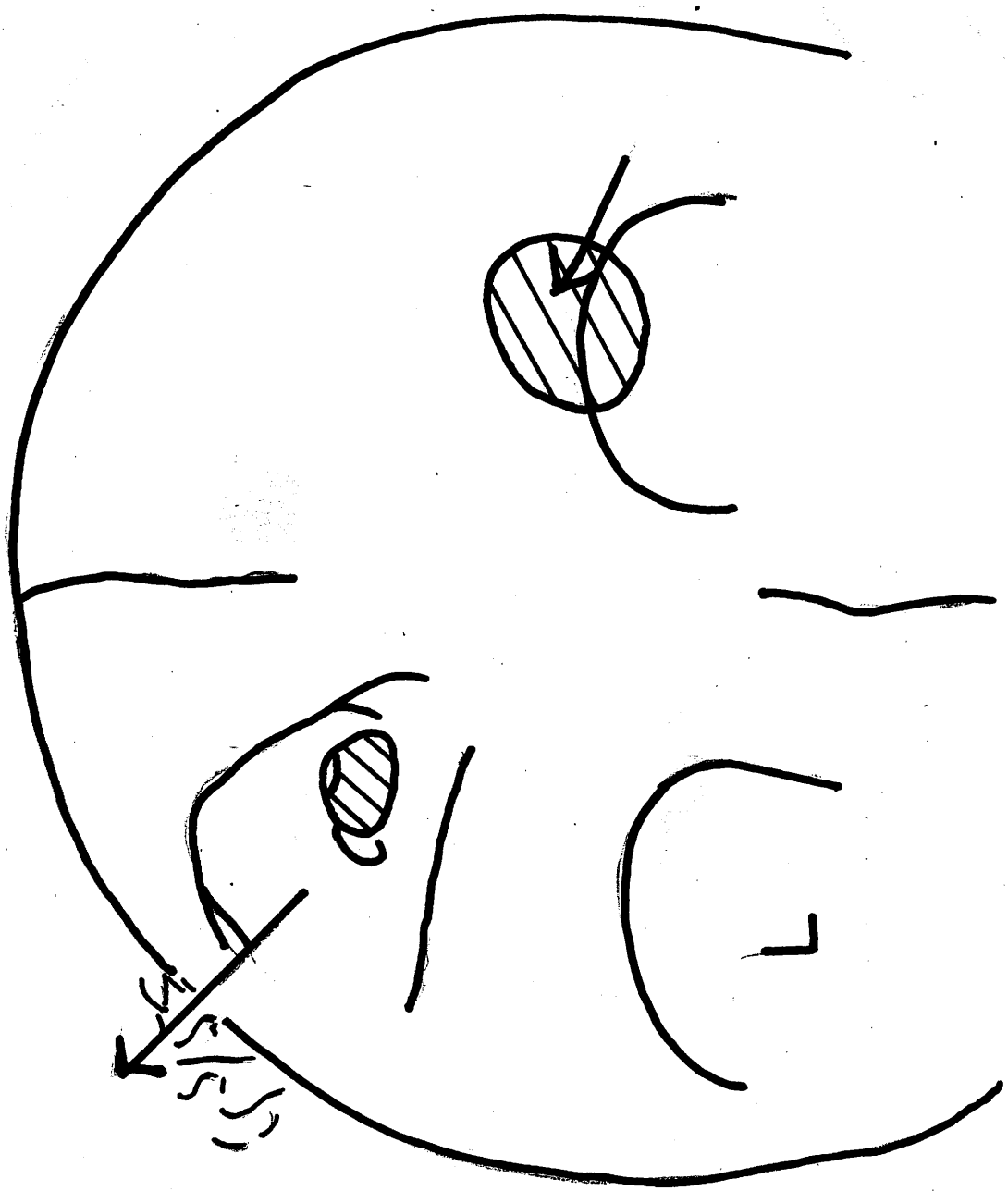
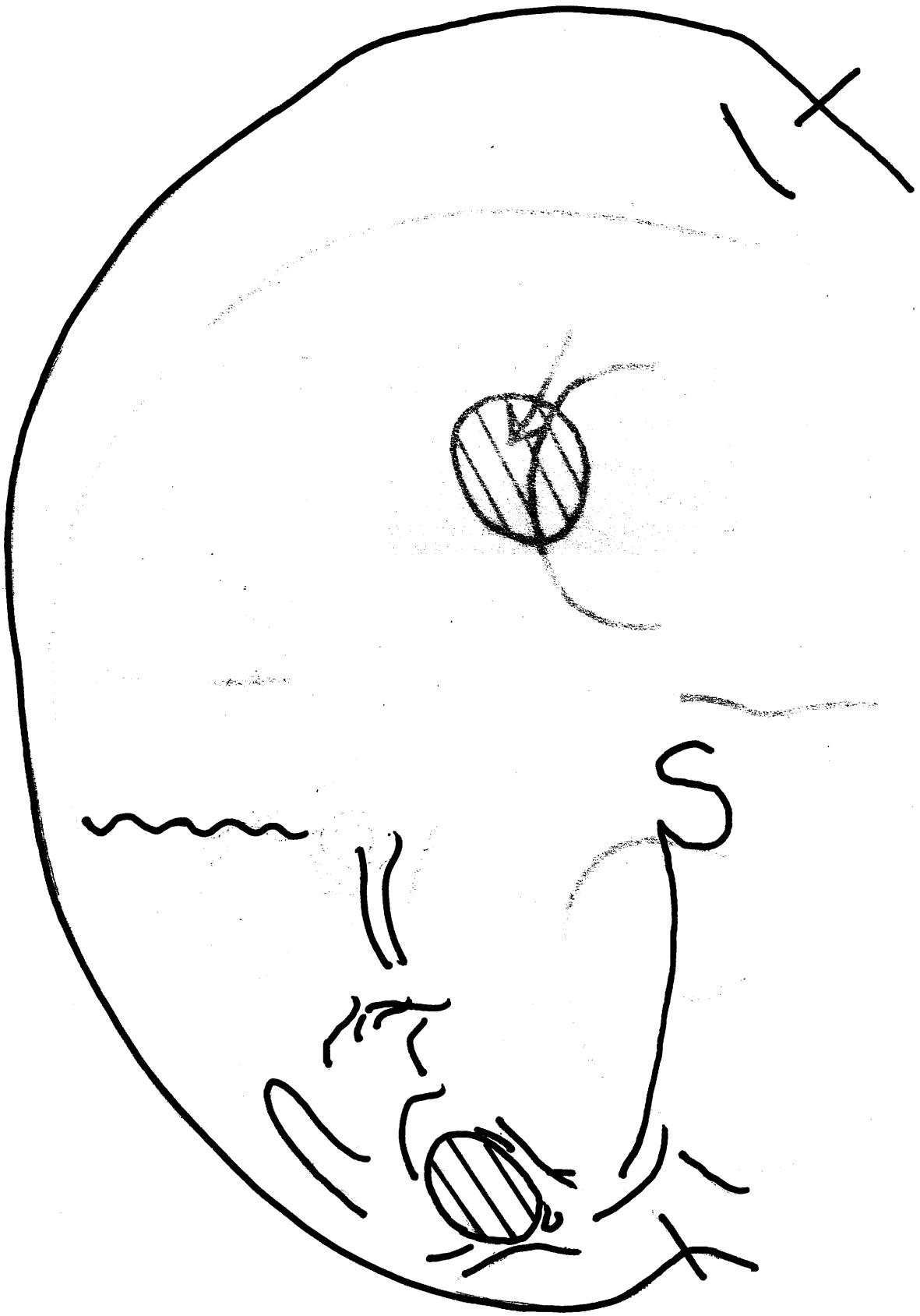


Figure 25.



1	2	3	4	5	6	7	8
FRONTAL	BILATERAL (7)						
3	SEE TEXT						
6 (753)	Thro' & thro' wound supraorbital region R.-L. involving both frontal poles At opn. considerable destr. anterior pt. both frontal lobes was observed (Fig. 25)	Few min.	4	-	Reported normal in early wks. of injury	0	Frontal sinuses involved. Bilateral anosmia. CSF rhinorrhoea L. Extradural aerocele
15 (621)	Entry L. orbit. MFB lodging in ant. parietal region R. side (Fig. 26). At opn. orbital surface L. frontal lobe found herniating thro' defect in floor of L. ant. fossa. Herniating portion cut flush w. floor & left in situ. Dural tear measured 3 x 1.5 cm.	0	2	Enlargemt. R. ant.horn & ant.pt. of body of vent.	-	0	Destruction of L. eye. Early sensory change L. side. L. hemiparesis including face. Bilateral anosmia
19 (965)	Supraorbital injury w. gross comminutn. of bone. At opn. good deal of bone & necrotic frontal lobe removed each side, leaving cavities in brain the size of walnuts (Fig. 27)	1 day	>28	Both ventricles sl. dilated but syst. symmet.	0	0	Marked apathy & confusion in early stage of injury. Bilateral anosmia
58 (984)	Entry R. supraorbital. Small metallic fragmt. indriven, traversing R. & L. lat. ventricles to lodge in L. frontal lobe (size of pre-op. bone defect 1 x 1 cm.). Sizeable subd. haematoma R. & quantity haematoma within missile canal. All haematoma, liquefied tissue & indriven bone fragmts. removed (Fig. 28)	Few secs.	1	-	Dysrhythmia sugg. deep midline focus	0	Drowsy & apathetic in early stages, otherwise no neurological signs

Figure 32.

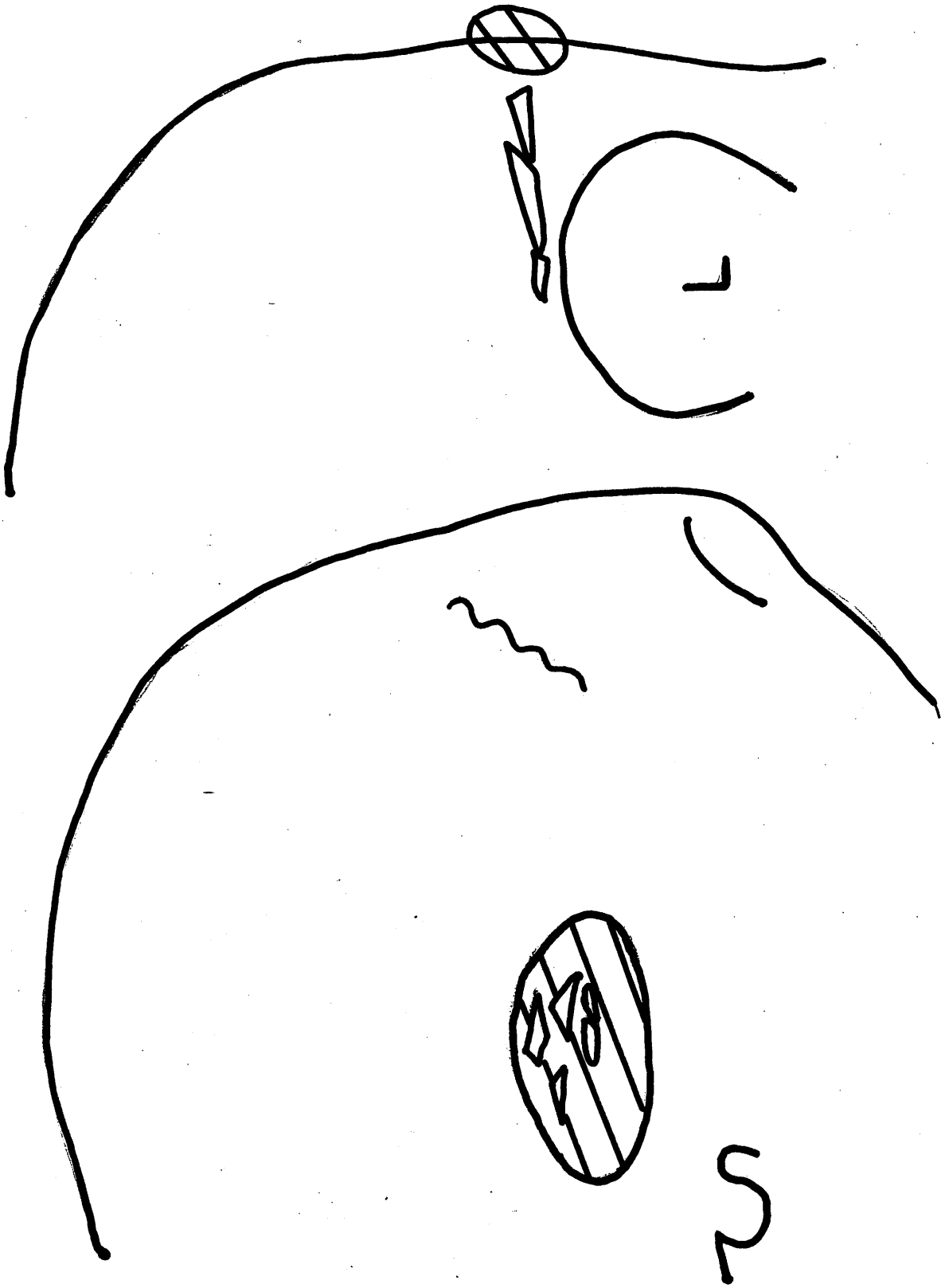


Figure 31.

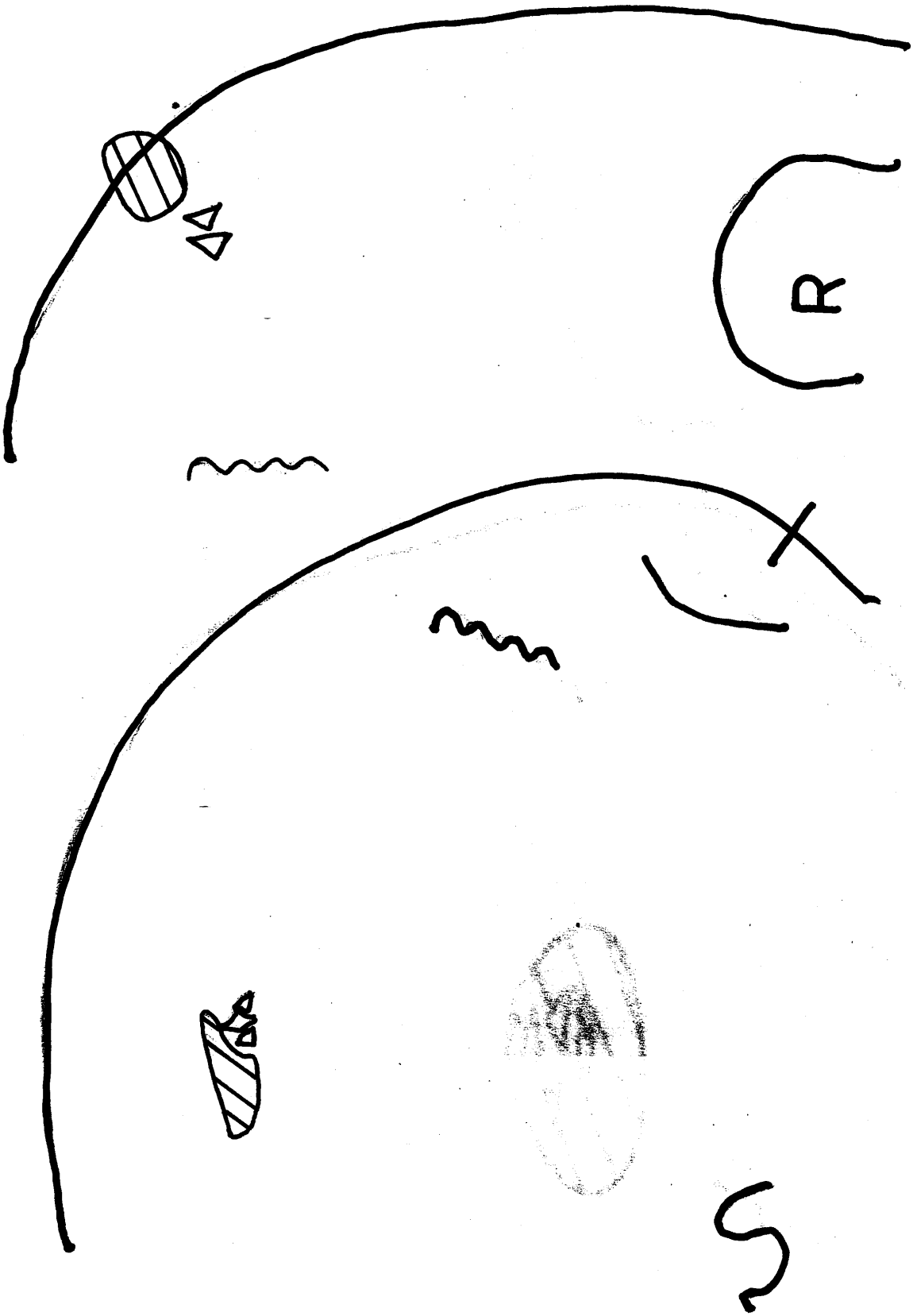


Figure 30.

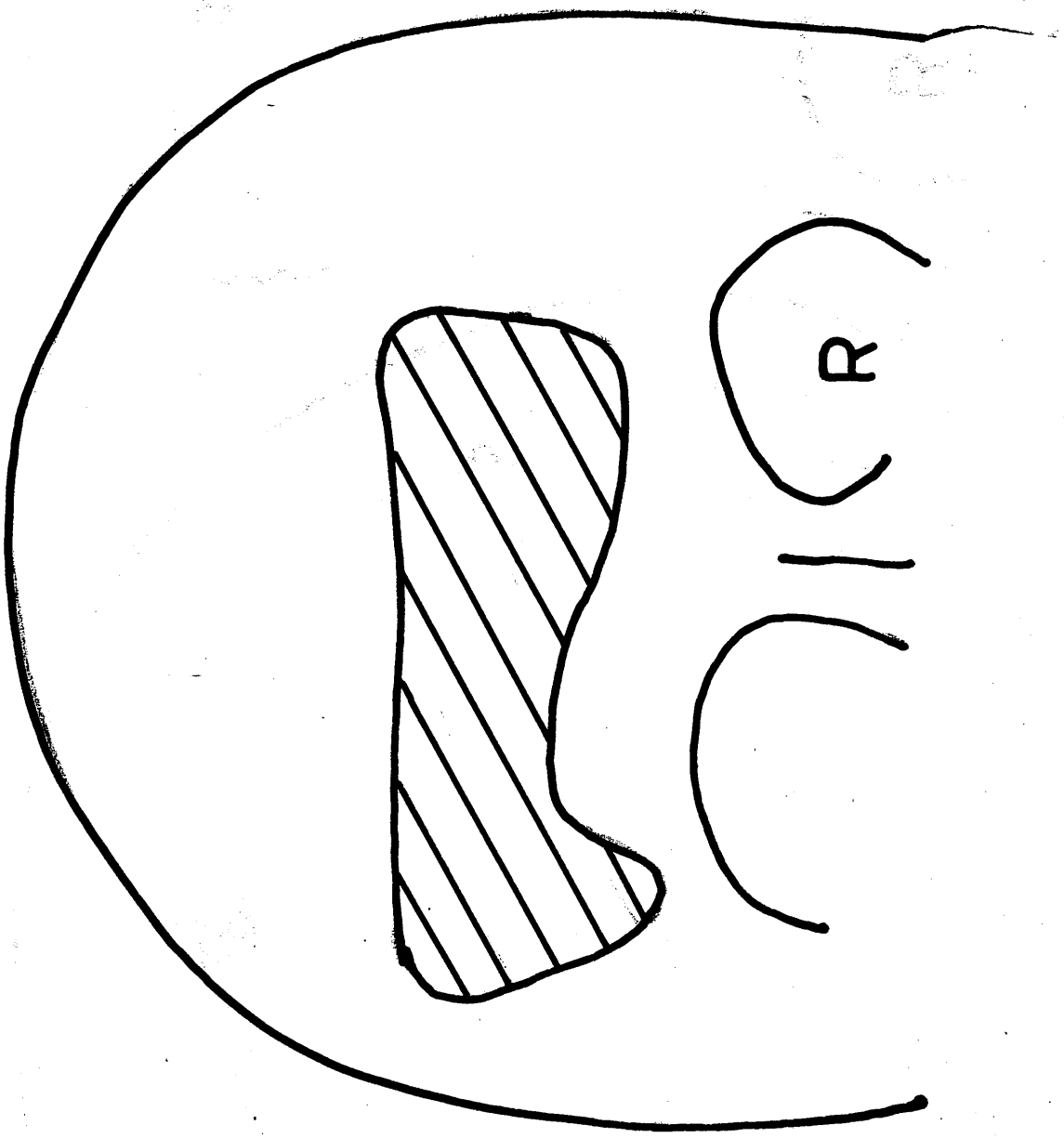


Figure 30.

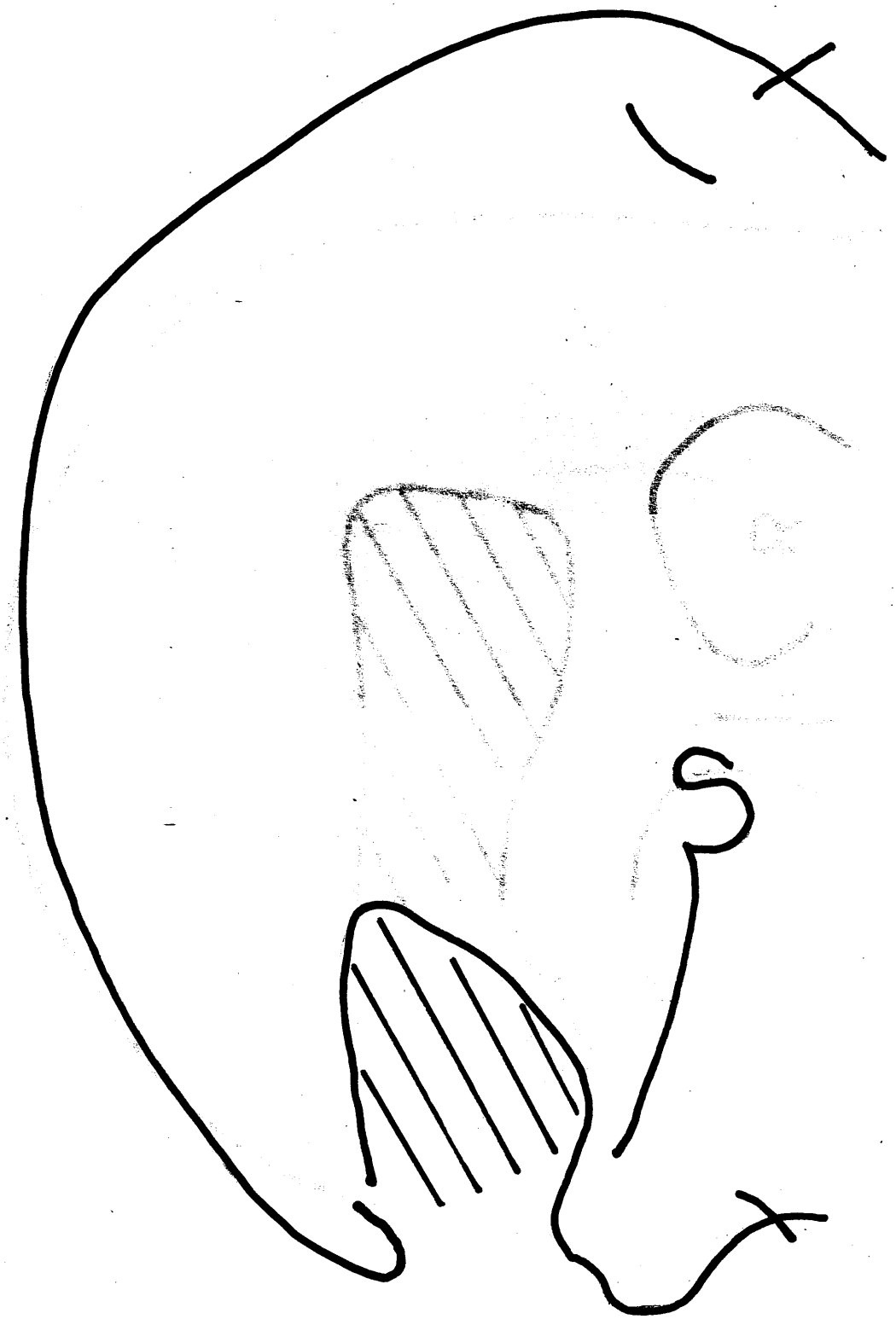
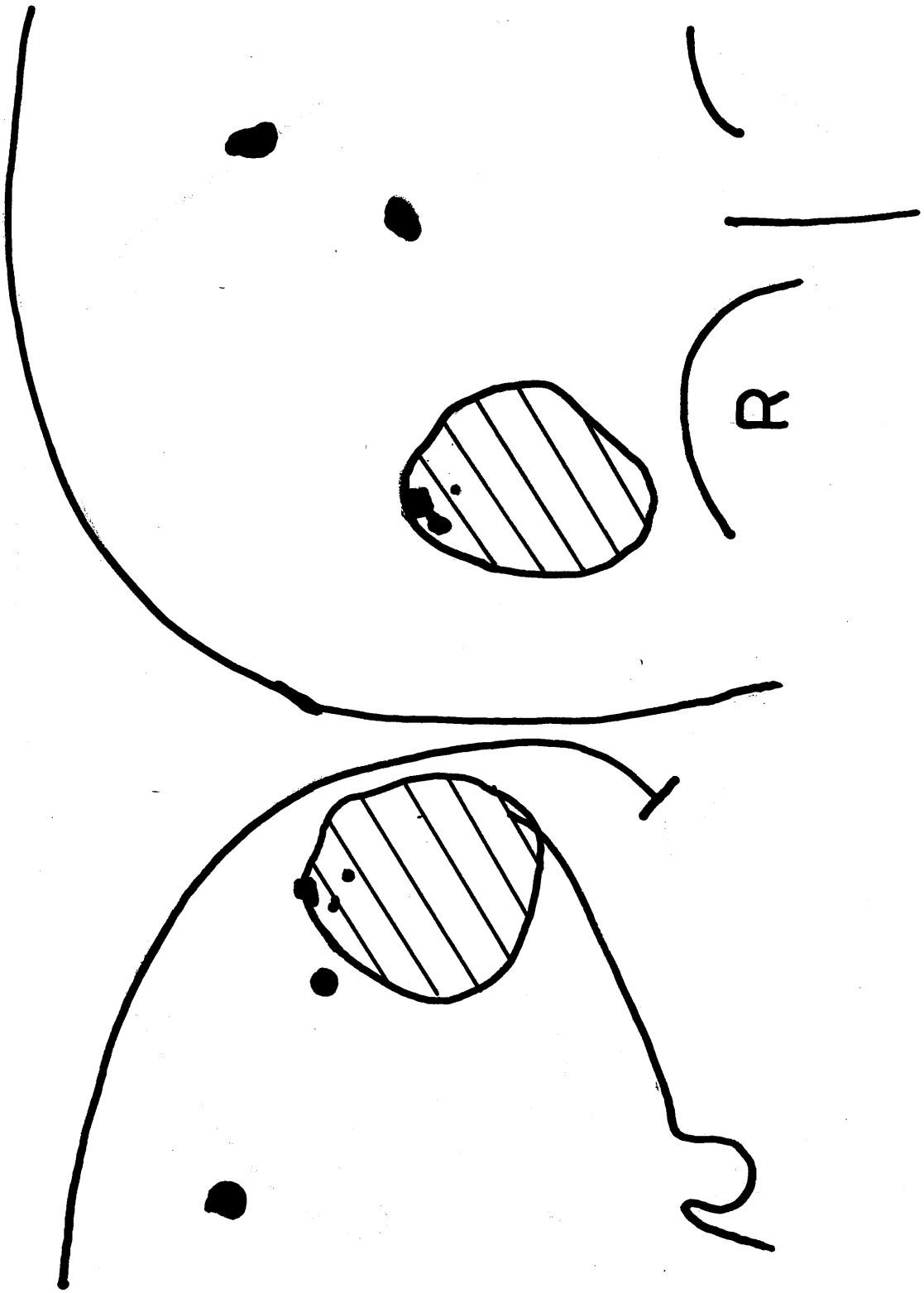
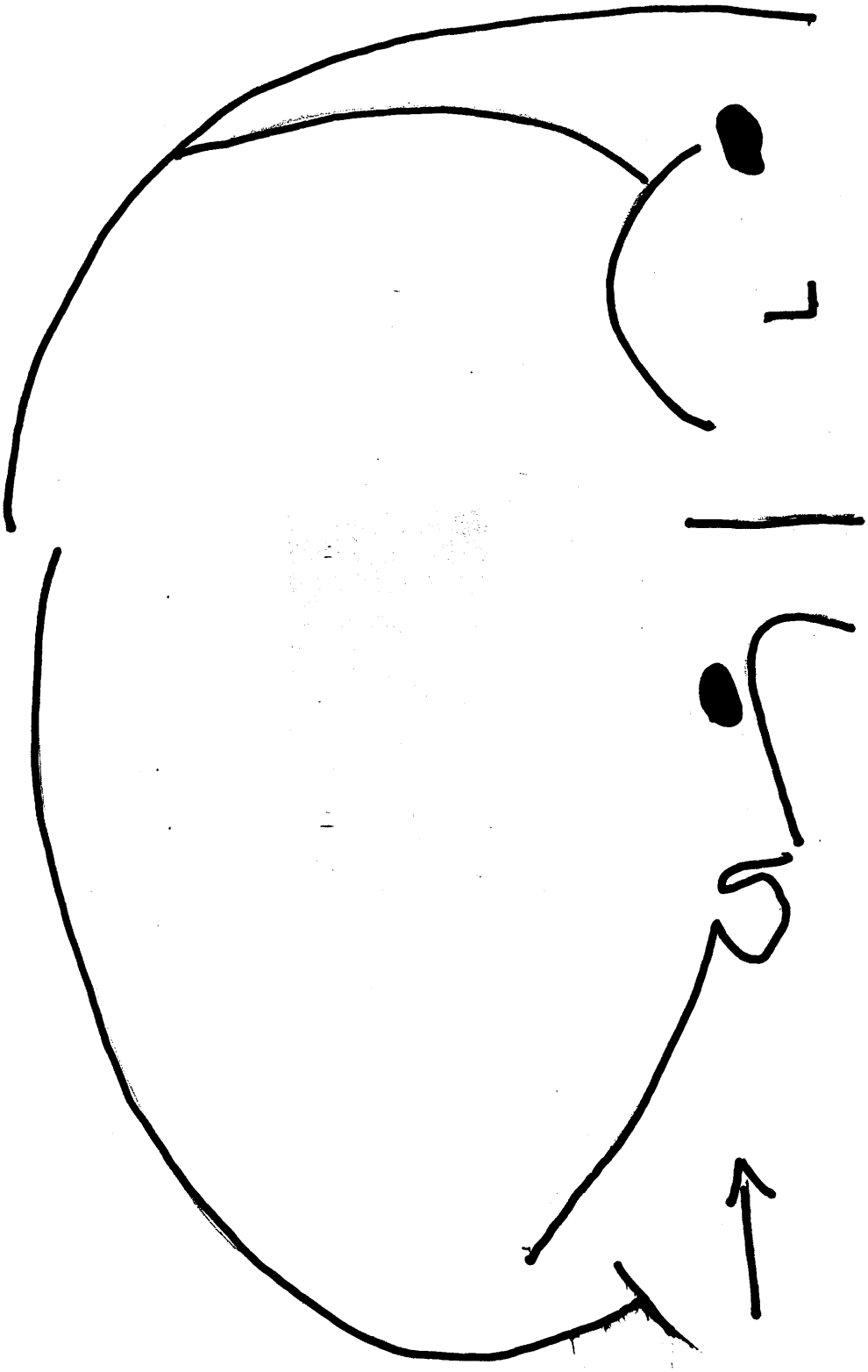


Figure 29.



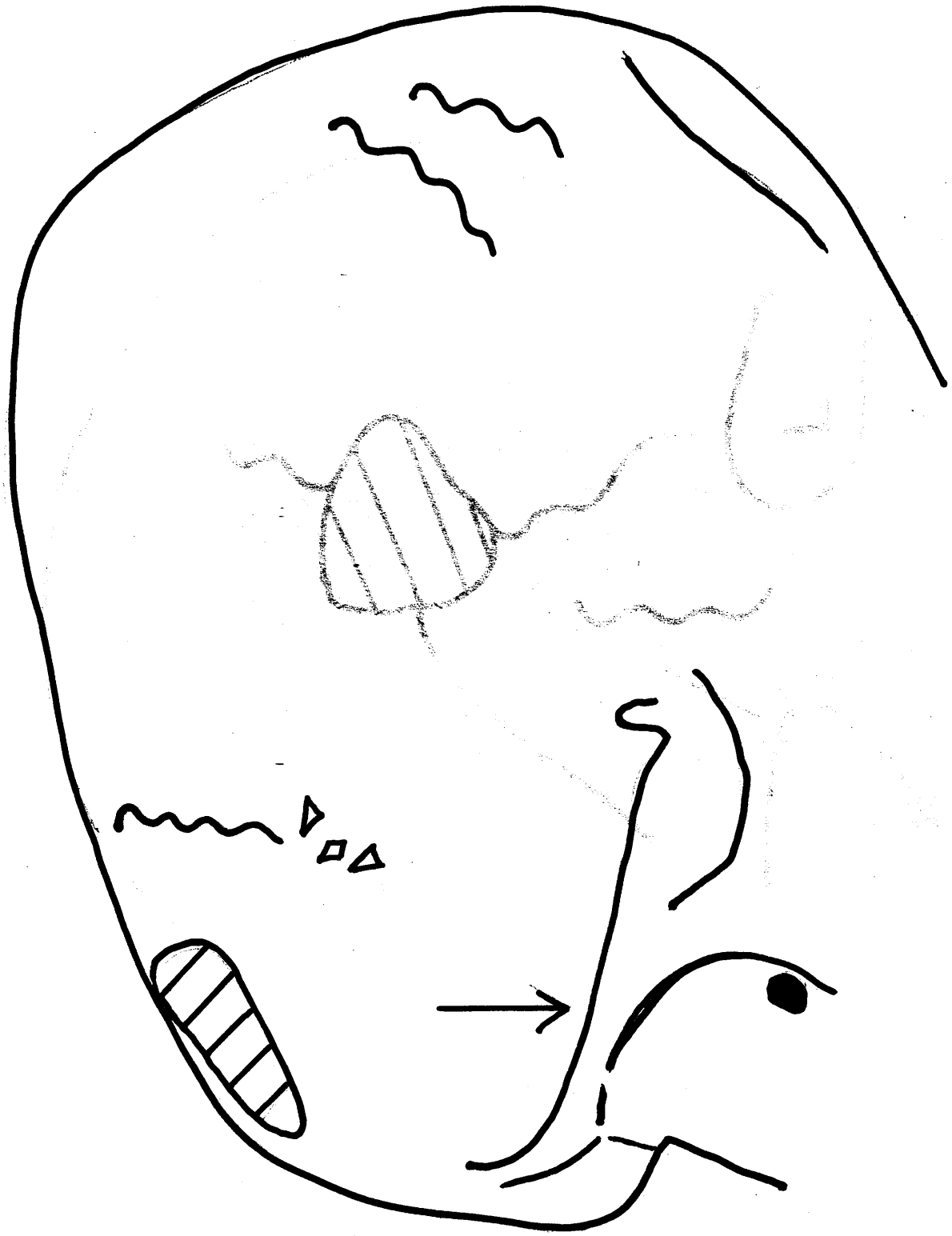
1	2	3	4	5	6	7	8
59 (999)	Entry R. supraorbital. 2 small metallic fragmts. indriven thro' R. frontal lobe, 1 to lie in L. frontal lobe just beyond falx. Liquefactn. of ant. pt. R. frontal lobe noted at opn. (Fig. 29)	Few secs.	Few hours	Syst.midline & symmet.	Paroxysmal (?)	0	Loss of R. eye (separate wound) No neurological signs
68 (226)	Supraorbital injury. Bilateral destruction of frontal poles (Fig. 30)	1 day	9	-	Focal spike L.frontal on overbreathing	0	L. hyposmia
PARIETAL RIGHT (1)							
66 (466)	Parasagittal. Dural defect 2.5 x 1 cm. Superficial brain cavity w. bone fragmt. & necrotic tissue removed at opn. (Fig. 31). Depth of penetratn. probably less than 1 cm., but incl. because severe signs indicate damage remote from site of injury	7 days	5	Whole system dilated w. sl.shift towards defect	Abnormal	0	Severe signs. Early confusion & disorientation. Denied ownership of L. arm. L. flaccid monoplegia & L. facial wkness.; wkness L. leg. Fine finger tremor L. hand. Upper L. quadrantanopia. Imp. senaatn. L. hand. Sl. L. ear deafness
PARIETAL LEFT (2)							
13	SEE TEXT						
42 (242)	Antero-inferior parietal wound. Bone fragmts. indriven to depth of 2 cm. Preop. bone defect 5 x 2 cm. Pulped brain & bone fragmts. sucked out of gutter-shaped track 5 cm. long x 2 cm. wide x 2 cm. deep (Fig. 32)	Few	3	-	Normal	0	Severe early dysphasia. R. upper quadrantanopia

Figure 33.



1	2	3	4	5	6	7	8
TEMPORAL LEFT (1)							
37 (986)	Entry L. orbit. Metallic fragmts. penetrated L. orbit to lodge in temporal lobe (Fig. 33) lateral to & below the temporal horn	0	Conscious for 30 mins. after injury then delayed P.T.A. of 21 d.	System central but shows some dilatatn.	-	+	Destruction of L. eye

Figure 34.



The following 4 records are given in detail to illustrate cases of severe wounding in which no intellectual deficit could be demonstrated.

Case 3 (M.R.C. No. 188).

This 24-year-old corporal was wounded on 4th August, 1944. The metallic foreign body entered the left frontal parasagittal region about 1.5 to 2 cm. to the left of the midline and 5 cm. above the supraorbital margin, crossed the midline and lodged in the floor of the right orbit, severely damaging the right eye, which eventually required enucleation.

At operation on 6th August, (Lt. A.N.Guthkelch) the bone defect in the left frontal region was enlarged to 3 x 4 cm. and the dural tear was enlarged to the limits of the defect. The cavity in the left frontal lobe was sucked out and the falx was seen to be torn. A cavity in the right frontal lobe was also sucked out. Five bone chips were removed. An X-ray examination on 9th August showed an operative defect in the upper part of the left frontal bone 3.5 cm. in diameter, extending almost to the midline. From this defect 3 bone fragments were indriven into the midline, the lower to lie just above the genu of the corpus callosum (Fig. 34).

An air encephalogram carried out on 28th September showed the upper and central part of the frontal lobe to be occupied by a series of large porencephalic cysts on the right side, extending to the tip of the frontal pole. The right lateral ventricle was filled and its outline was within normal limits. In none of the pictures did there appear to be any filling of the left frontal horn.

A further X-ray on 2nd November showed that the multiple porencephalic cysts on the right had coalesced to form a large aerocele which communciated with the ventricular system.

An A.E.G. on 7th December showed air to be present in the right lateral ventricle only. This communicated anteriorly with a large cerebral cyst which lay above and anterior to the frontal horn. The body of the ventricle was normal in position, with no evidence of shift.

When admitted to the Military Hospital for Head Injuries on 7th August he could give no history of his wound and could not remember going to France. He knew

he was in hospital in Oxford, his name, age, and the year, but said the month was November. He was drowsy and slightly irritable. The right eye was exophthalmic, with periosteal haematoma; power was equal and good in the arms, and he was able to move both legs.

The next day he was restless and kept pulling the dressing off his head. By 10th August he was less drowsy, but now thought he was in France. He knew the month and the year and said he felt better. By the 14th he lay still in bed with his eyes closed, and was very drowsy and apathetic. When roused he cooperated fairly well for a minute or so and then relapsed.

By 5th September he was still drowsy, but cooperative on examination. His memory for events before the injury had come back to a point shortly before he was hit, and the P.T.A. was about a week in duration. He answered questions quickly and intelligently, but did not volunteer information. He gave the impression of being a tired, bored man.

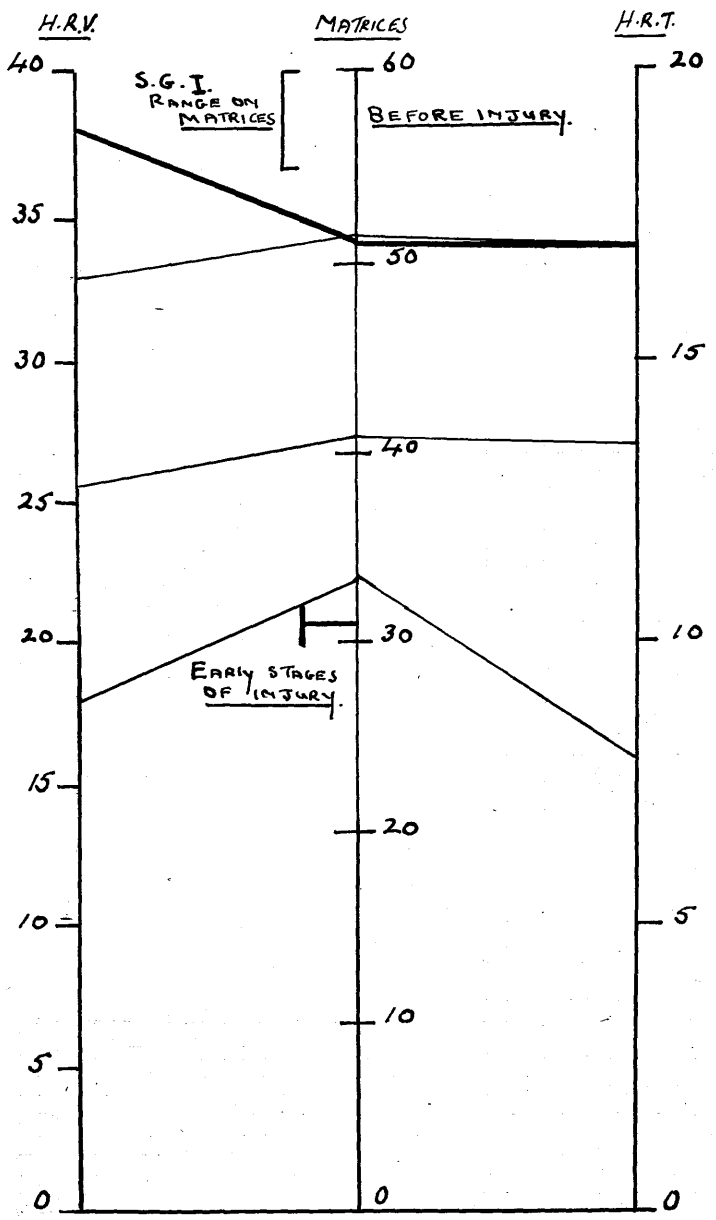
On 11th September he was reported to have been drowsier during the preceding 3 days and lay in bed sleeping. He answered reasonably when questioned, but slowly and after hesitation. Two days before he had sat for an hour with a thermometer in his mouth, owing to an oversight on the part of the nursing staff, and made no objection.

By 5th October he was still wetting his bed at times. He answered quickly and intelligently to questioning and cooperated fully on examination, but with an air of bored unconcern during the procedure. He had some weakness of hand grip and wrist movements on the left, but there were no other abnormal signs.

By 28th October he was getting up again, and there was no further incontinence of urine. He developed C.S.F. rhinorrhoea, and on 7th November had an operation performed for dural repair (Major Calvert), at which fascial grafting of a large hole in the dura over the posterior wall of the right frontal sinus, and a second large hole over the left frontal sinus, was carried out. A scar in the left frontal lobe containing 2 bone chips and possibly a third was excised from the point of entry through the cortex down through the remnants of the falx to the cystic area in the right frontal lobe.

The following extracts from Major Calvert's operation notes are given in detail so that an accurate picture may be obtained of the amount of frontal lobe tissue destroyed in this case:

Figure 35.


H.R.V.
MATRICES
H.R.T.
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25
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40
30
20
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0
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10
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0
S.G.I. RANGE ON MATRICES
BEFORE INJURY.
EARLY STAGES OF INJURY.

"A transverse incision was made in the dura over the right frontal lobe. The frontal pole was found herniating down through a hole in the dura, and the cranial wall of the right frontal sinus and anterior ethmoids. The brain was here cut through at the base of the protrusion, leaving the herniated portion in situ. The right frontal lobe was occupied by a large cyst, communicating with the right ventricle. This was opened, with the escape of a large quantity of C.S.F. It was found that the cyst extended to the midline and was adherent to the left frontal lobe through a large defect in the falx. The hole in the dura on the right side measured 1.5 x 1.25 cm.

"A similar transverse incision was now made over the left frontal pole. There was a hole in the dura over a hole of similar size in the posterior wall of the left frontal sinus through which brain was herniating. The protruding brain was cut off at its base, leaving the herniated portion in situ. The left frontal scar was dissected out from the cortex level down to the wall of the cyst in the right frontal lobe and to, but not into, the anterior horn of the left ventricle posteriorly."

His progress during the next 3 weeks was stormy, with fluctuating temperature and increased clumsiness of the left hand. He had periods of drowsiness, when he became irrational and disorientated, and incontinence reappeared.

On 3rd January, 1945, he had an epileptic attack, and by then his general condition was improving. During the morning he lay in bed, sleeping or doing nothing, but got up in the afternoons. His wife stated that he tired quickly in conversation, and after a short time would make nonsensical remarks; she regarded his mental state as greatly improved as compared with 2 weeks previously. He was invalided home in February, 1945.

He was examined by the author at Headington Hill Hall when he returned for review of his case in January, 1952.

In spite of the severe destruction of frontal lobe tissue there is very little in the way of intellectual impairment, if any at all (Fig. 35). When tested in the early stages of his injury on 6th September, 1944, by the late W.R.Reynell, he was reported to be a "man of superior intelligence, showing little evidence of impairment". The Matrices were not done at this time. On 9th January, 1945, when recovering from his severe set-back, he produced a point score of 31 on the Matrices. This score is an indication of his poor intellectual functioning at this

stage in his recovery. When tested by the author on 19th February, 1952, 7½ years after injury, he was able to produce a score of 51 on the Matrices and 17 on the H.R.T. These scores were within the expected range for the vocabulary level reached (38). The only information about his pre-traumatic mental testing which could be obtained from his Army documents was that he was graded as S.G. I. The actual score on the Matrices was not given, but this information would indicate that it was in the region of 55+, which is rather higher than his latest score. As has been pointed out, the overall selection grade would have been assessed on other tests as well as the Matrices, of which a vocabulary test would have been one. It is a reasonable conclusion, therefore, that he is functioning at much the same level as before injury.

He was educated at a grammar school, which he left at 16. He took the general school certificate at 15, with passes in 8 subjects, reaching matriculation standard in all subjects except French. Before entering the Army he was employed as a clerk with the G.P.O.

Case 13 (M.R.C. No. 950).

This 19-year-old private was wounded by a mortar fragment in Korea on 17th November, 1951. On admission to an American Neurosurgical Detachment 20 hours after injury he was semi-conscious, opened his eyes on stimulation, but made no response to commands. There was a scalp laceration measuring 5 x 2 cm. in the left parietal region, with clotted blood, bone fragments and cerebral tissue presenting. The wound was grossly contaminated with leaves, dirt, and debris. A skull film showed deeply indriven bone fragments.

At operation the same day (Lt-Colonel Meirowsky) the huge fungating mass was resected to skin level. Inspection revealed a large bi-parietal bone defect, with the medial border of the large dural defect immediately adjacent to the sagittal sinus, which was not torn but may have been thrombosed. A large amount of liquefied brain tissue, clots and innumerable bone fragments were evacuated, and the left side of the falx was exposed widely. The left anterior cerebral artery had to be clipped. All softened tissue was resected to a depth of approximately 7 cm., where bone fragments were encountered. The removal of one fragment resulted in the escape of ventricular fluid from a tear in the third ventricle, which may have been obstructed by a comminuted piece of bone. There was one large vessel just posterior to this tear which had to be clipped. The surface diameter of the wound after resection of all the devitalised tissue measured 4 cm. to the left of the falx, and the

Figure 38.

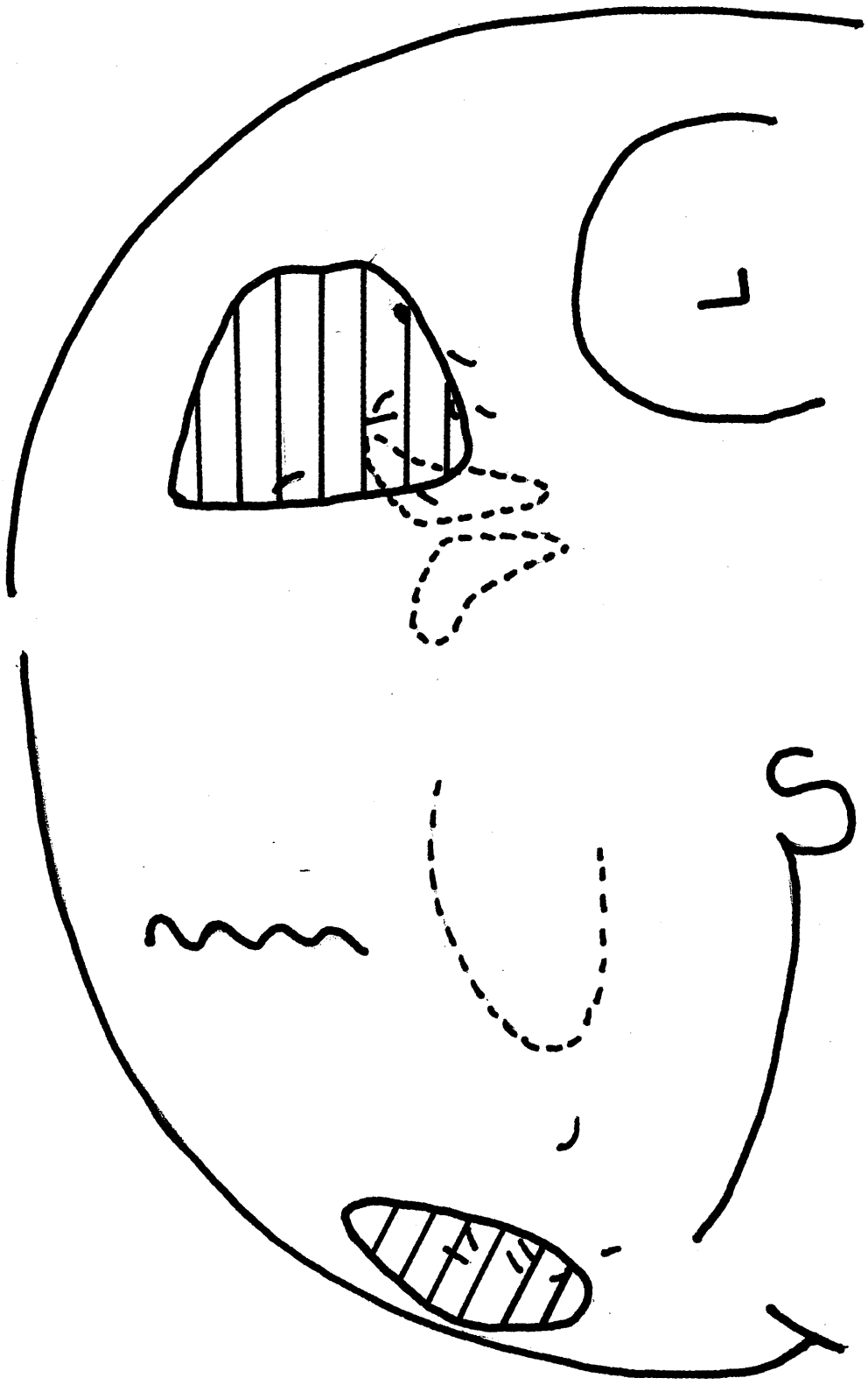
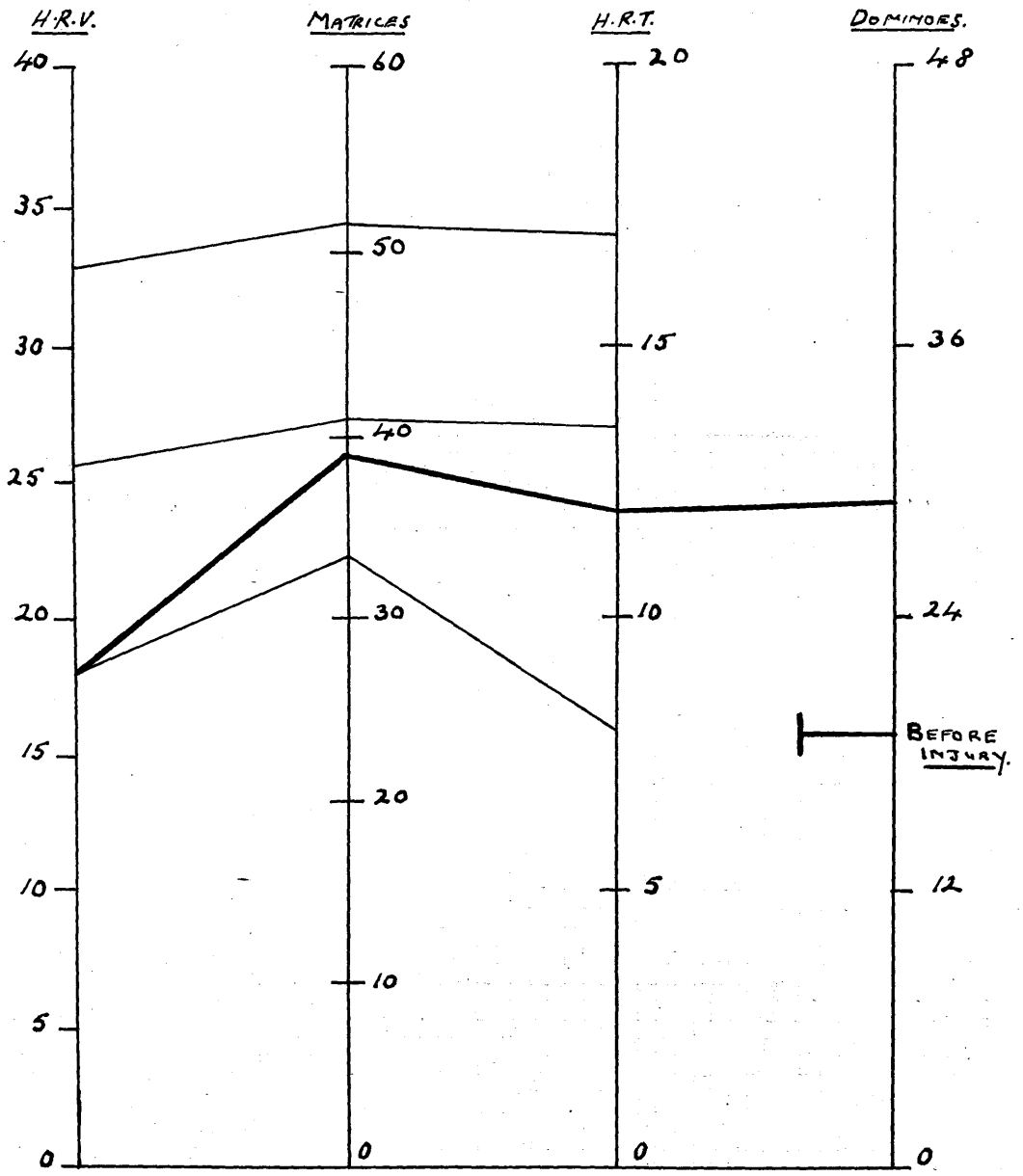


Figure 37.


H.R.V.
MATRICES
H.R.T.
DOMINOES.
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15
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50
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30
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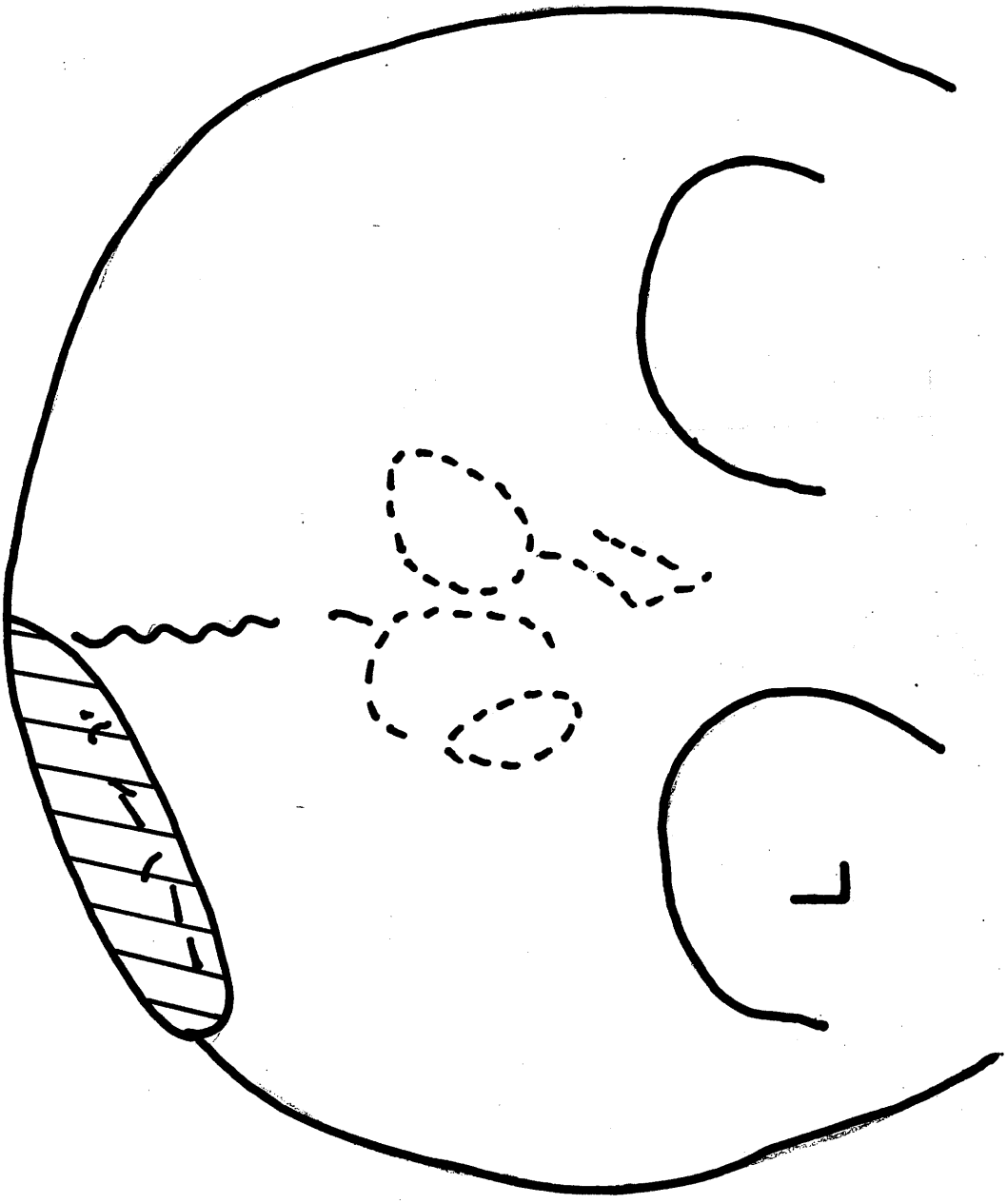
0
20
15
10
5
0
48
36
24
12
0
BEFORE INJURY.

Figure 36.



antero-posterior diameter was also approximately 4 cm. The depth of the wound was approximately 7 cm. and at that level its diameter was not larger than 2 cm.

Postoperatively the patient did well. There was a right facial paresis, complete right hemiplegia, and complete motor aphasia, but he followed simple commands. The left arm was spastic and paretic. Skull films taken on 4th December, 1951, showed a left anterior parietal craniectomy site measuring approximately 6 cm. in length, with numerous dural clips about the defect. No intracranial bone fragments were noted (Fig. 36).

He was admitted to the Military Hospital for Head Injuries on 3rd January, 1952. He was completely orientated and the R.A. was estimated as a few minutes, the P.T.A. as 10 days. He was no longer dysphasic. He had a right spastic hemiplegia with cortical sensory loss in the right limbs.

An A.E.G. showed some dilatation of both lateral ventricles, particularly of the anterior horns and main part of the body. The left was more dilated than the right.

An E.E.G. showed a dysrhythmia confined to the left parasagittal area, with no evidence of deeper damage.

Mental testing was carried out on 12th June, 1952, seven months after injury (Fig. 37). On the Matrices he produced a score of 39, a score of 12 on the H.R.T., and 29 on the Dominoes. All these scores were consistent with the vocabulary level reached (18). When tested on Army entry on 20th November, 1950, his score on the Dominoes was 19, giving him an S.G. of IV on this test, as compared with a present grading of III+. His overall S.G. on the battery of tests used on Army entry was IV. He was then regarded as a youth with "below average intelligence and ability".

He left school at 14, was an average scholar, and had held a series of simple labouring jobs until he entered the Service.

Case 35 (M.R.C. No. 973).

This 19-year-old private was wounded in Korea on 19th November, 1951, sustaining a penetrating wound of the left frontal region (Fig. 38). He was admitted to an American neurosurgical unit within 3½ hours of being found wounded. He was then stuporous, but fairly rational. There was a 4 cm. stellate laceration in the left frontal region anterior to the hair-line, and through this defect cerebral herniation

Figure 36.

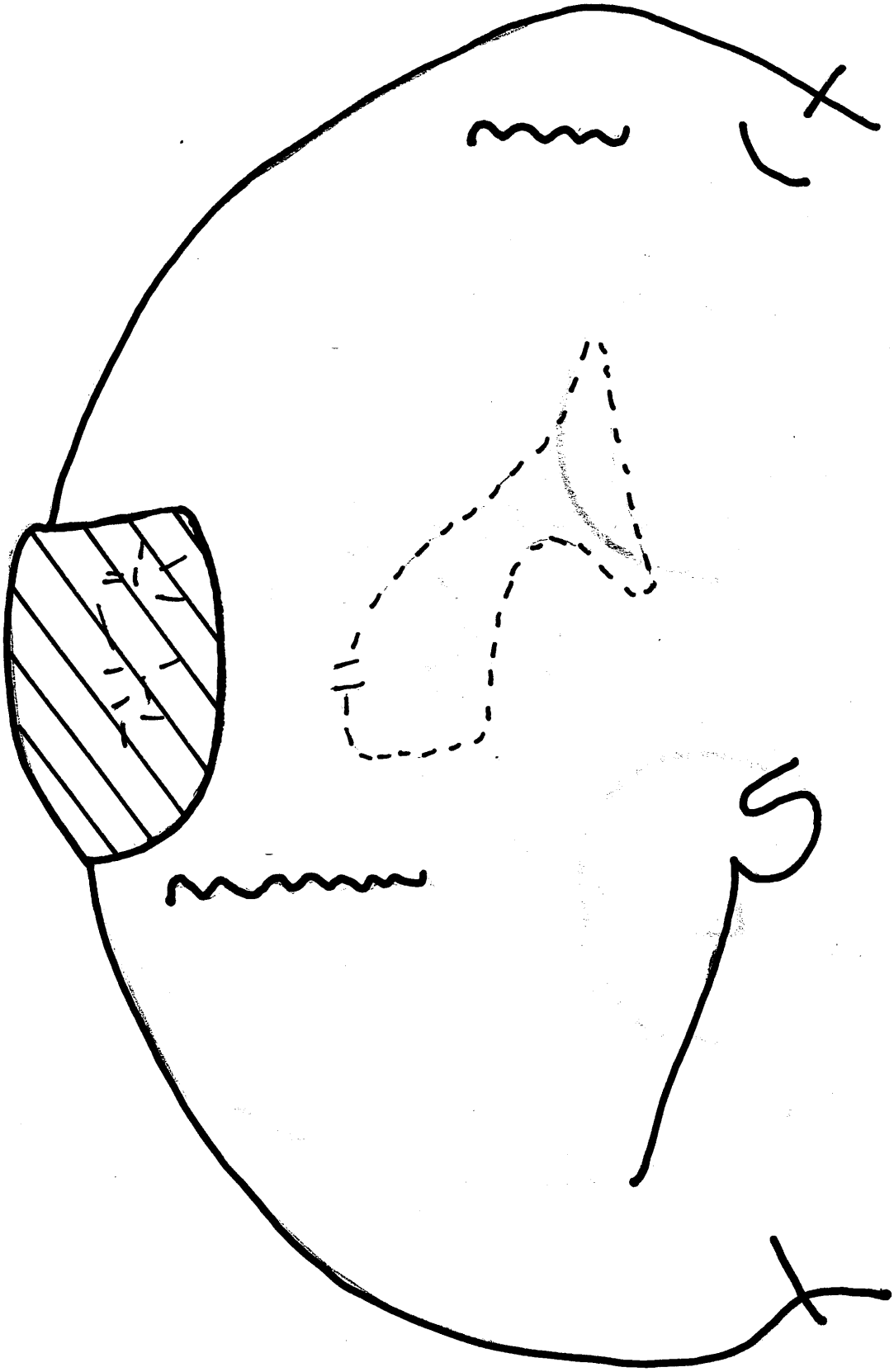
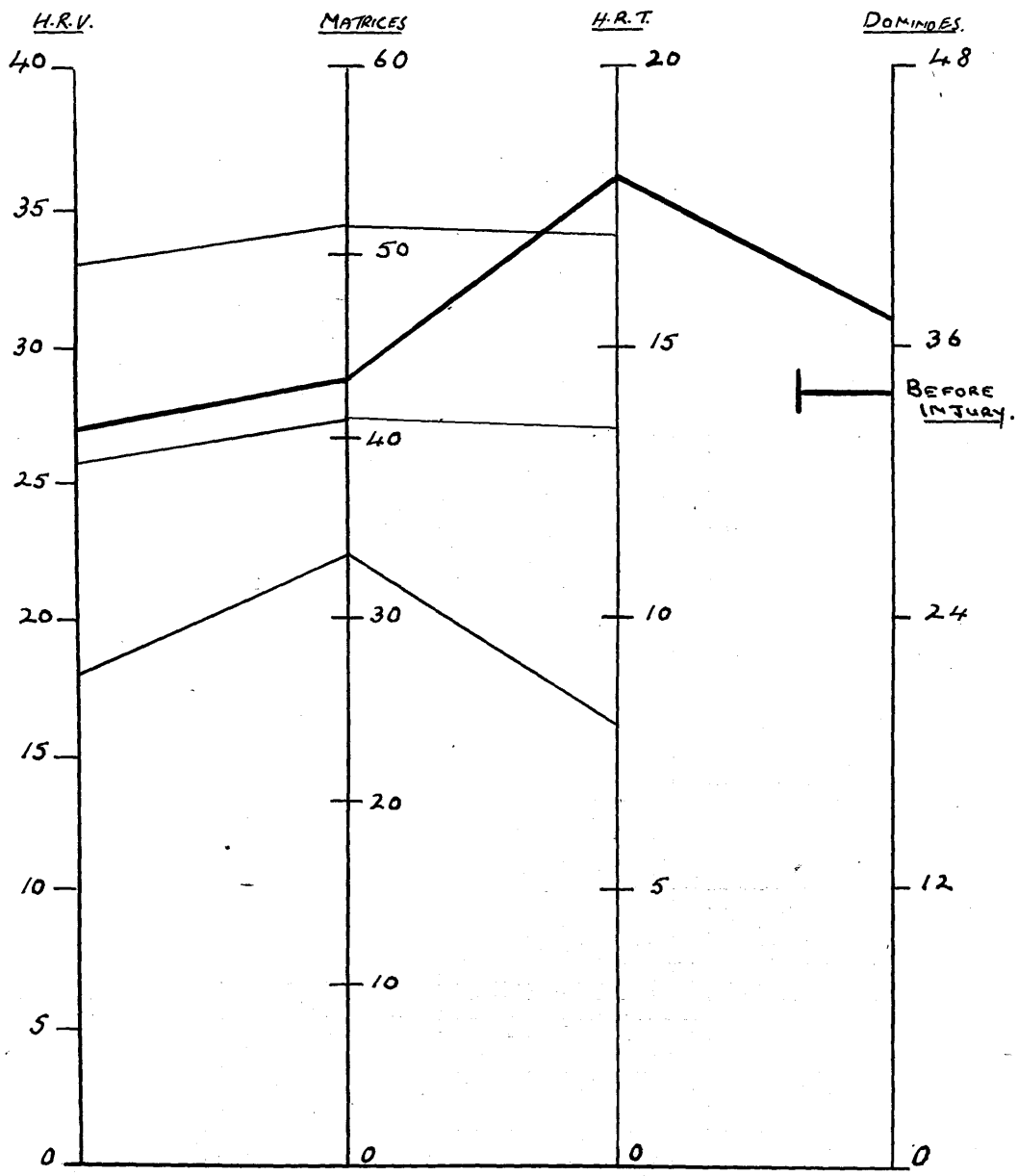


Figure 39.


H.R.V.
MATRICES
H.R.T.
DOMINOES.
40
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25
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15
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5
0
60
50
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30
20
10
0
20
15
10
5
0
48
36
24
12
0
BEFORE INJURY.

was present.

At frontal craniectomy (Lt-Colonel Meirowsky) the scalp laceration was debrided and the craniectomy extended into the left frontal sinus. Many embedded bone fragments and liquefied cerebral tissue were removed. The post-operative course was uneventful, but X-ray revealed 4 retained intracranial bone fragments at a depth of approximately 7 cm., as measured from the anterior left frontal bone. A second left frontal craniectomy was performed on 25th November, and the retained bone fragments were removed. His course after this was also uneventful.

On admission to the Tokyo Army Hospital on 8th December, 1951, he was alert, rational and well orientated. Cranial nerves were intact, fundi normal, and there was no facial weakness. There was good strength in the upper and lower limbs, and sensation was intact. Deep tendon reflexes were equal and active.

On admission to the Military Hospital for Head Injuries In January, 1952, he had no complaints and was fully orientated. Retrograde amnesia was a few seconds; post-traumatic amnesia 3 days. There was no neurological deficit on examination, and an air encephalogram was normal.

Mental testing was carried out on 30th September, 1952, almost a year after injury (Fig. 39). On the Matrices he produced a basic score of 43. His performance, however, was rather erratic, and he showed a rapid, careless approach when doing the test. This is to some extent revealed in his sub-test scores (i.e., his individual scores on sets A, B, C, D, E, of the Matrices) which were 12, 7, 10, 8, 6 (43). He was given an opportunity to correct this score, and his corrected score was 52 (12, 12, 11, 10, 7). On the H.R.T. he produced a score of 18, and on the Dominoes a score of 37. These scores are consistent with corrected score on the Matrices and with the vocabulary level reached (27). The vocabulary level is perhaps a little lower than might have been expected from his performance on the problem-solving tests, but is not inconsistent with his cultural background. When tested on Army entry on 22nd July, 1950, his score on the Dominoes was 34, giving him an S.G. II on this test, which is the same as his present S.G. His overall S.G. on the battery of tests used on Army entry was III+. He was regarded as of fair education and good average intelligence.

He left school at 14, was an average scholar, and had been a house decorator since then, having completed an apprenticeship.

Figure 41.

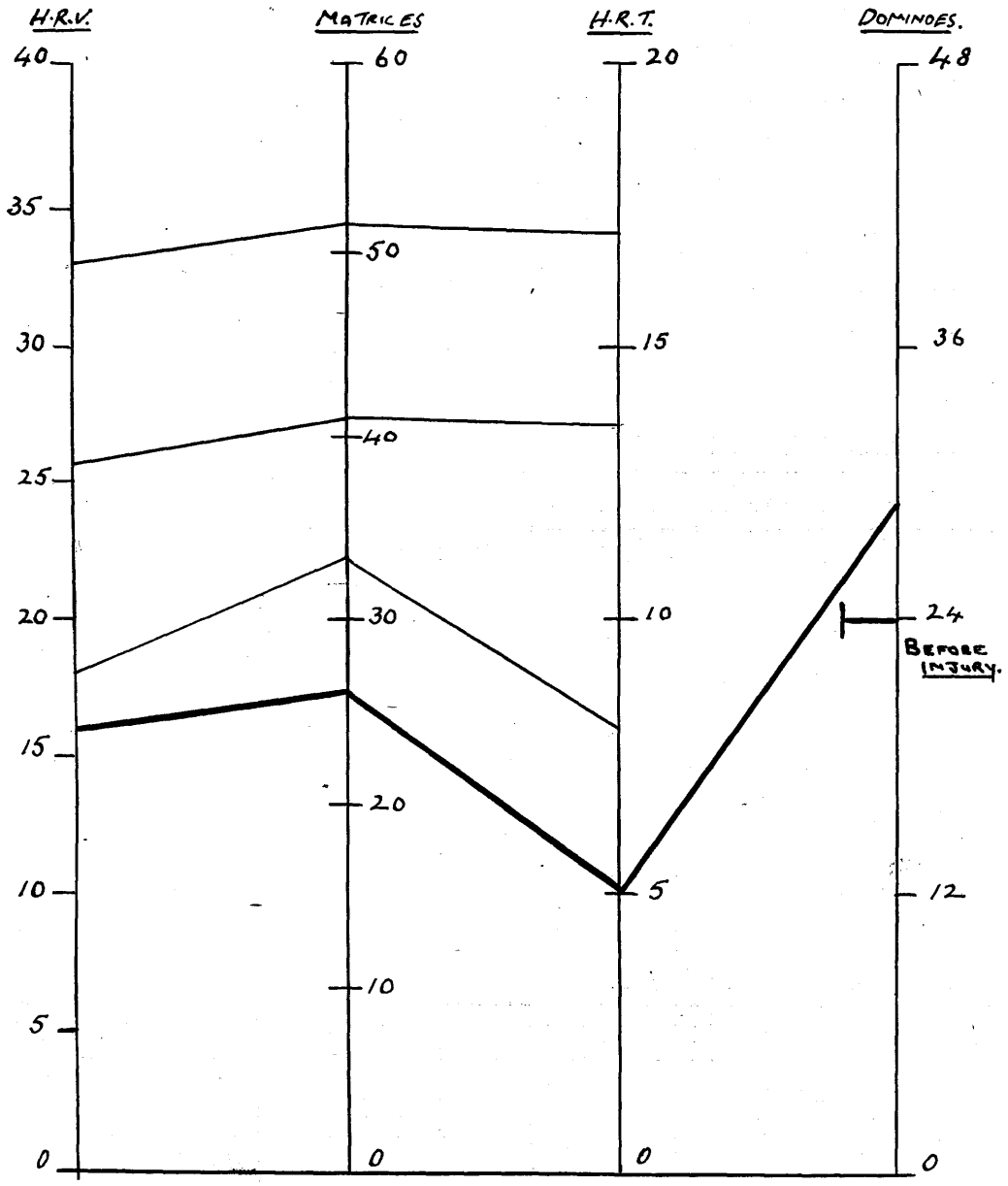
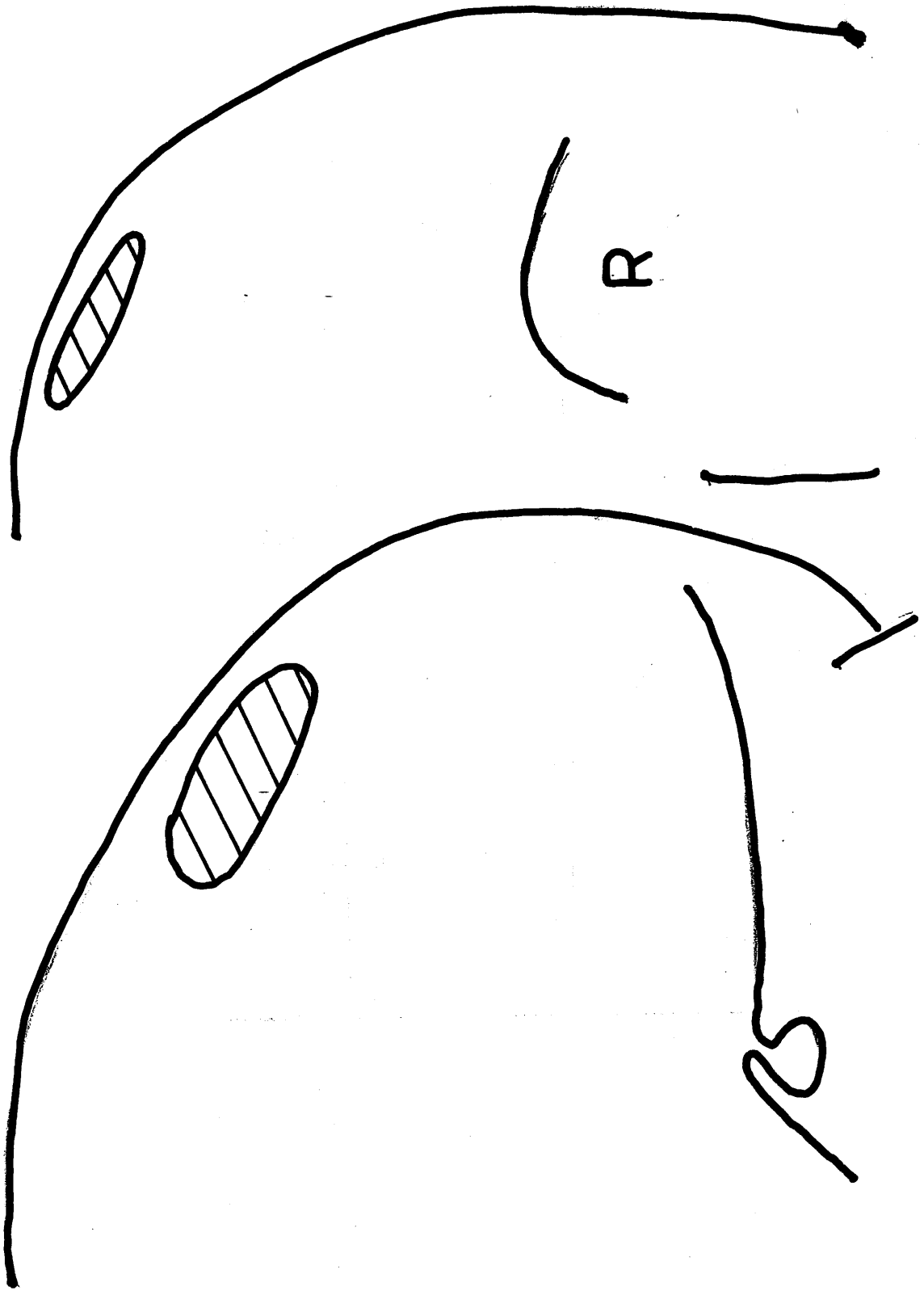

H.R.V.
MATRICES
H.R.T.
DOMINOES.
40
35
30
25
20
15
10
5
0
60
50
40
30
20
10
0
20
15
10
5
0
48
36
24
12
0
BEFORE INJURY.

Figure 40.



Case 55 (M.R.C. No. 1003).

This 19-year-old private was wounded in Korea on 5th March, 1953. On admission to an American neurosurgical unit a few hours after wounding he was drowsy, but orientated. Skull films showed a complete small-arms bullet just to the right of the midline in the posterior frontal region, with many indriven fragments leading down to it. He had no neurological signs apart from suggestive seventh and eighth cranial nerve weakness.

At operation (Major A.F.Kingman) on the same day a 1.5 cm. depressed fracture was revealed just at the coronal suture, and clean dura was exposed right round the penetration. There was a minimal subdural haematoma. The missile track was debrided of all necrotic brain and palpable bone fragments. The anterior horn of the right lateral ventricl had been transected, and as the missile could not be found it was presumed that it had fallen back into the ventricle. When the patient was turned on his face the missile then gravitated downward and could be felt. It was very difficult to extract it because of its large size and the depth at which it was situated, but it was finally teased out with the forefinger, considerable brain damage being done in the process.

After operation the patient had a left hemiplegia. He gradually became more alert but slept most of the time.

On admission to the Tokyo Army Hospital on 10th March he was conscious, but lethargic and somewhat confused, with a right central facial paresis in addition to the left hemiplegia. Skull films showed a 3 cm. surgical defect in the frontal region just to the right of the midline near the coronal suture without depressed bone fragments or foreign bodies (Fig. 40).

On admission to the Military Hospital for Head Injuries on 11th May, 1953, he had a spastic left hemiparesis, but had been walking for 6 weeks. There was a left extensor plantar response, but no sensory disturbance. The R.A. was nil, and the P.T.A. was estimated as approximately a week. No focal or paroxysmal activity was revealed by an E.E.G.

Mental testing was carried out on 29th May, 1953, three months after injury (Fig. 41). On the Matrices he produced a score of 26, a score of 5 on the H.R.T., and 29 on the Dominoes. All these scores were consistent with the vocabulary level reached (16). When tested on Army entry on 11th July, 1951, his score on the Dominoes was 24, giving him an S.G. of III- on this test, as compared with a present grading of III+. His overall S.G. on the battery of tests used on Army entry was V. He was regarded as a man of

"little intelligence, with very poor education and very little general ability."

He left school at 15, and was a poor scholar. He was employed as a general labourer before entering the Army.

Certain points must now be summarised concerning the nature of the injuries in the 38 cases described above.

Where the injury was represented by apparently little more than an area of superficial cortical damage, as in the 15 cases in Group II (a), then no intellectual deficit could be demonstrated. In this group, point scores on the Dominoes Test obtained before injury were available in 10 cases for comparison with the scores obtained after injury. In only 2 of these 10 was the score lower than that obtained before injury, and in each case the difference was only 1 point. In the other 8 cases the score had remained the same in 2 and had increased in 6 by amounts varying from 2 to 9 points. It can be seen, therefore, that as far as re-testing on the Dominoes Test is concerned, in these cases the effect is exactly the same as that obtained in the normal controls - namely, that the scores tend to rise.

The passage of a small metallic fragment between one cerebral area and another in 3 cases (Group II (b)) seemed to have little effect on general intellectual functioning.

In the remaining 20 cases (Group II (c)) the wounds extended deeply into homologous cerebral areas, and in 16 cases this meant the frontal lobes.

A study of these frontal lobe cases readily shows that

they were for the most part severe injuries involving one or other frontal lobe or causing extensive bilateral destruction. In the main the injury was confined to the anterior parts of the lobes, but it should be noted that in certain cases it extended sufficiently far back to cause motor signs. In none of these cases could intellectual deterioration be demonstrated. In view of the fact that in the previous section of the results it has been shown that wounds passing deeply into the posterior part of the frontal lobe on either side (Group Ib) caused an unequivocal intellectual deficit, it might be asked why the wounds in the present section which pass far enough back to cause motor signs should not also produce some deficit. It is impossible to give a definitive answer to this question, but it may partly lie in the direction of the wound.

In the posterior frontal wounds of the previous section (Group Ib) the missile or bone fragments had passed very deeply inwards and downwards from the mid-lateral surface, or very deeply into the centre of the frontal lobe from above, presumably into areas where the long association tracts (superior longitudinal fasciculus) are concentrated. In the present cases, where the wounds have passed posteriorly the missiles have entered the frontal lobes in an antero-posterior direction, usually through the supra-orbital region, or obliquely from the supero-lateral or supero-medial aspects.

Group III - Doubtful Cases.

There are 15 cases in which intellectual functioning appeared to be doubtfully impaired (Nos. 2, 9, 11, 14, 16, 22, 29, 30, 36, 43, 48, 51, 57, and 64).

In 5 of these cases pre-traumatic scores were available on the Dominoes Test and the fall in score since injury had been 4 points or more. (Group IIIa)

In the other 10 cases no pre-traumatic scores were available and either the scores on the problem-solving tests were low compared with the vocabulary levels or there were inconsistencies in the levels reached on different problem-solving tests. (Group IIIb)

(a) Cases showing a fall of 4 or more points on the Dominoes Test since injury.

The details of mental testing with relevant comments on the 5 cases in this group are given in Table VII, while the anatomical and neurological details are given in Table VIII.

TABLE VII. DETAILS OF MENTAL TESTING BEFORE AND AFTER INJURY, OTHER INFORMATION AND COMMENT IN 5 CASES IN WHICH THE DOMINOES SCORE HAS FALLEN BY 4 OR MORE POINTS SINCE INJURY.

1	2	3	4	5	6	7	8	9	10	11	12
Case & Index Nos.	H.R.V.	H.R.T.	Matrices Score	Matrices S.G.	Dominoes After Injury Score	Dominoes After Injury S.G.	Dominoes Before Injury Score	Dominoes Before Injury S.G.	Minus Diff. in Points	Other Information	Comment
9 (962)	22	5	30	IV	15	IV	22	IV	7	Overall S.G. on Army entry (21.7.50) = IV - "Below average intelligence with limited powers of observation". Poor civilian employment record; approved school from 13-15. Matrices score on 2.10.45 = 30 (G.IV) - "Not able to do sums as well now". Nervous, depressed, schizoid.	Scores on all problem-solving tests are a little down compared w. vocabulary level. It is difficult to be dogmatic about general intellectual loss or even a specific loss on Dominoes, in view of emotional disturbance. Probably functioning within his normal intellectual range. Dyscalculia (?)
14 (969)	26	13	33	IV	22	IV	26	III-	4	Overall S.G. on Army entry (19.1.51) = IV - showed "few apparent aptitudes" & "frontal lobe apathy" & an erratic response when tested. Corrected Matrix score to 44 (G. III)	Scores on problem-solving tests show inconsistencies. Intellectual functioning impaired at this stage. No absolute deficit
16 (967)	29	16	41	III-	28	III+	33	II	5	Average S.G. on Army entry = III+ (2.2.51) - "average intelligence". S.G. on verbal test was II.	Little evidence of absolute impairment; probably functioning within normal range.

1	2	3	4	5	6	7	8	9	10	11	12
38 (987)	24	14	50	II	31	III+	37	11	6	Overall S.G. on Army entry (25.6.51) = II. "Plenty of intelligence."	Scores on problem-solving tests show slight inconsistencies. A minor degree of impaired intellectual functioning at this stage but no absolute deficit.
57 (998)	20	7	37	IV	17	IV	27	III-	10	Overall S.G. on Army entry (6. 4. 51) = V. "Average intelligence but educationally backward." I.Q. (27. 7.48) = 88. History of difficulty in recognising and forming figures since injury.	General intellectual functioning unimpaired. In this case the fall of 10 points on Dominoes after injury would appear to be due to a specific dyscalculia interfering with his performance on this test.

Figure 44.

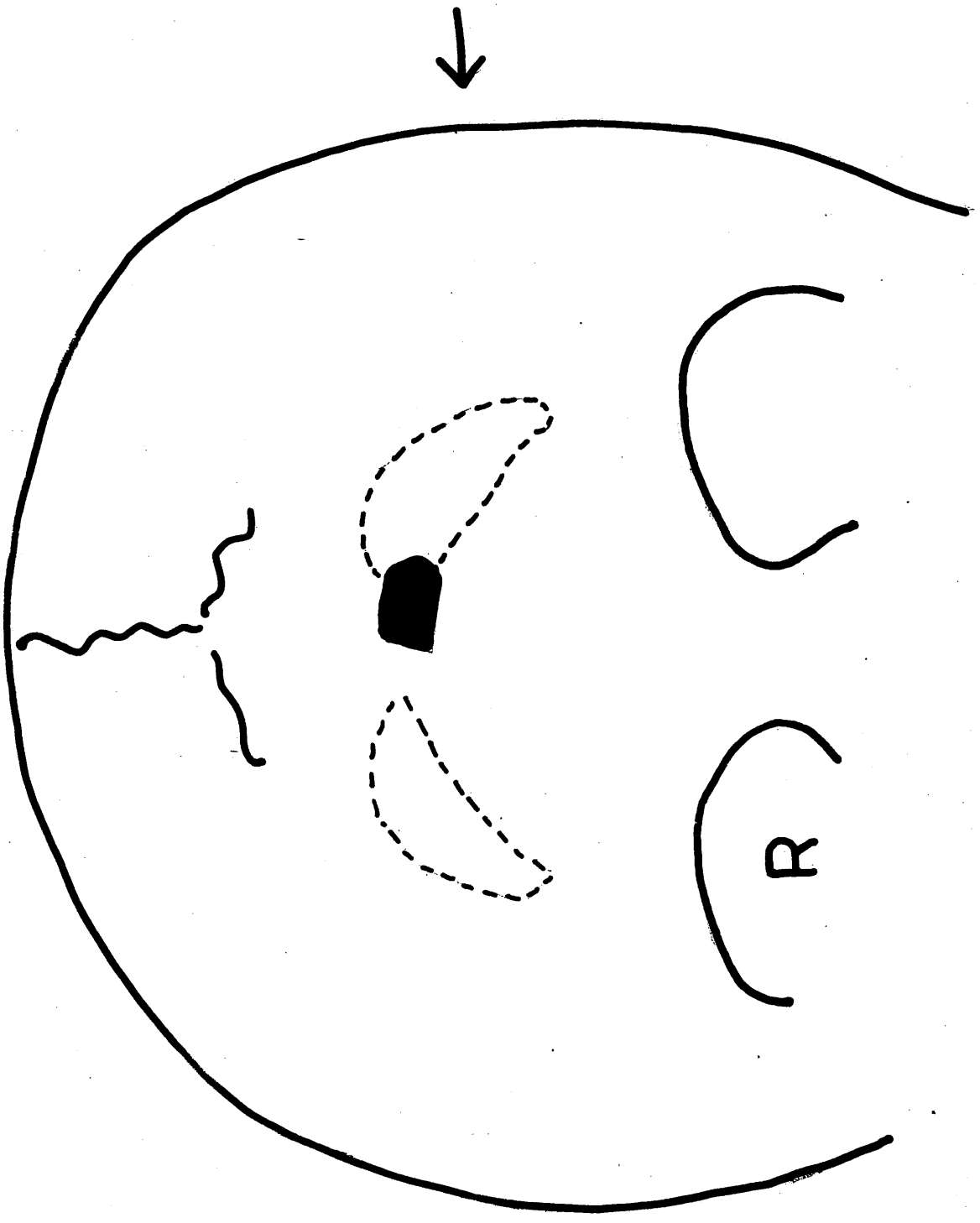


Figure 44.

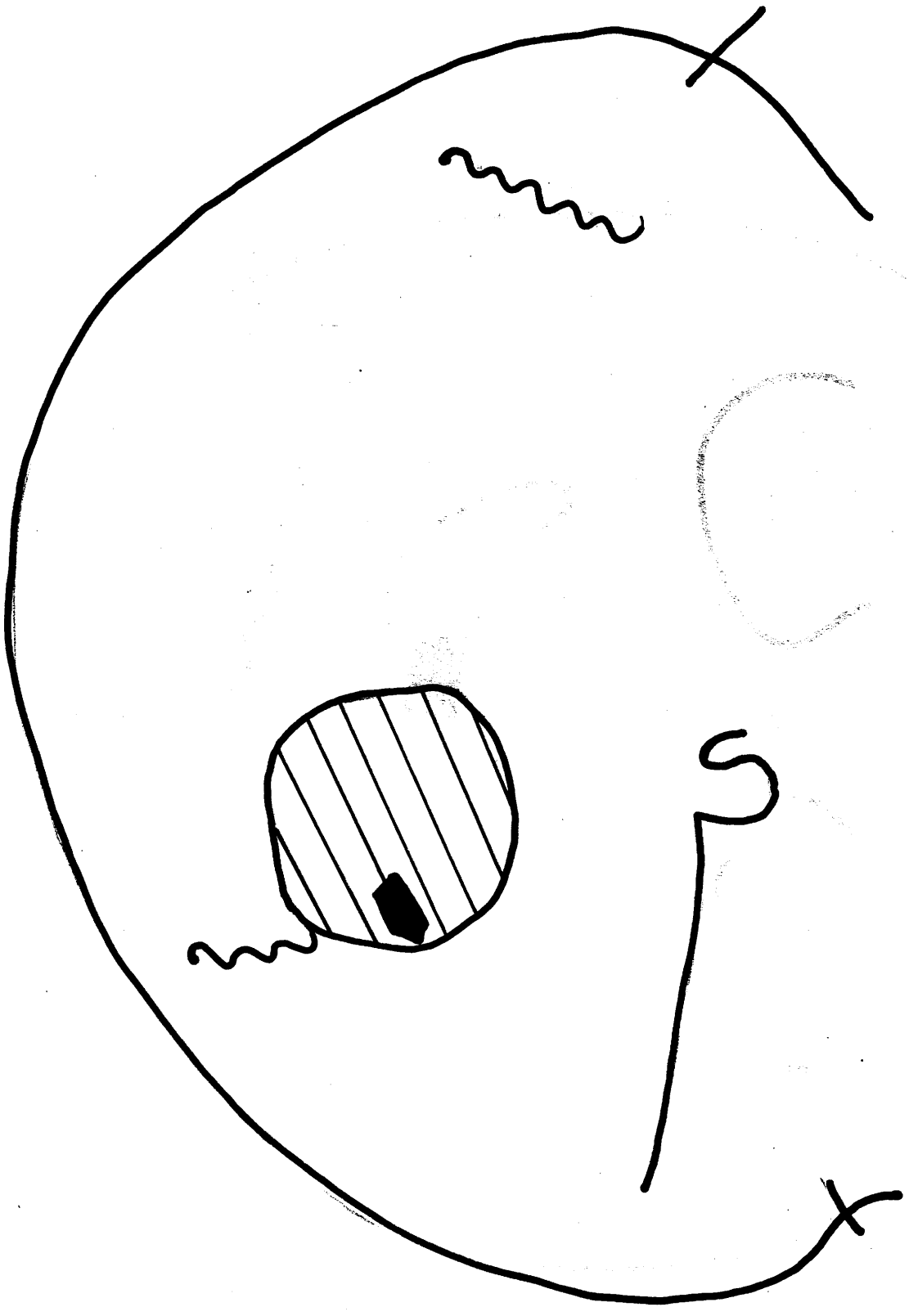


Figure 43.

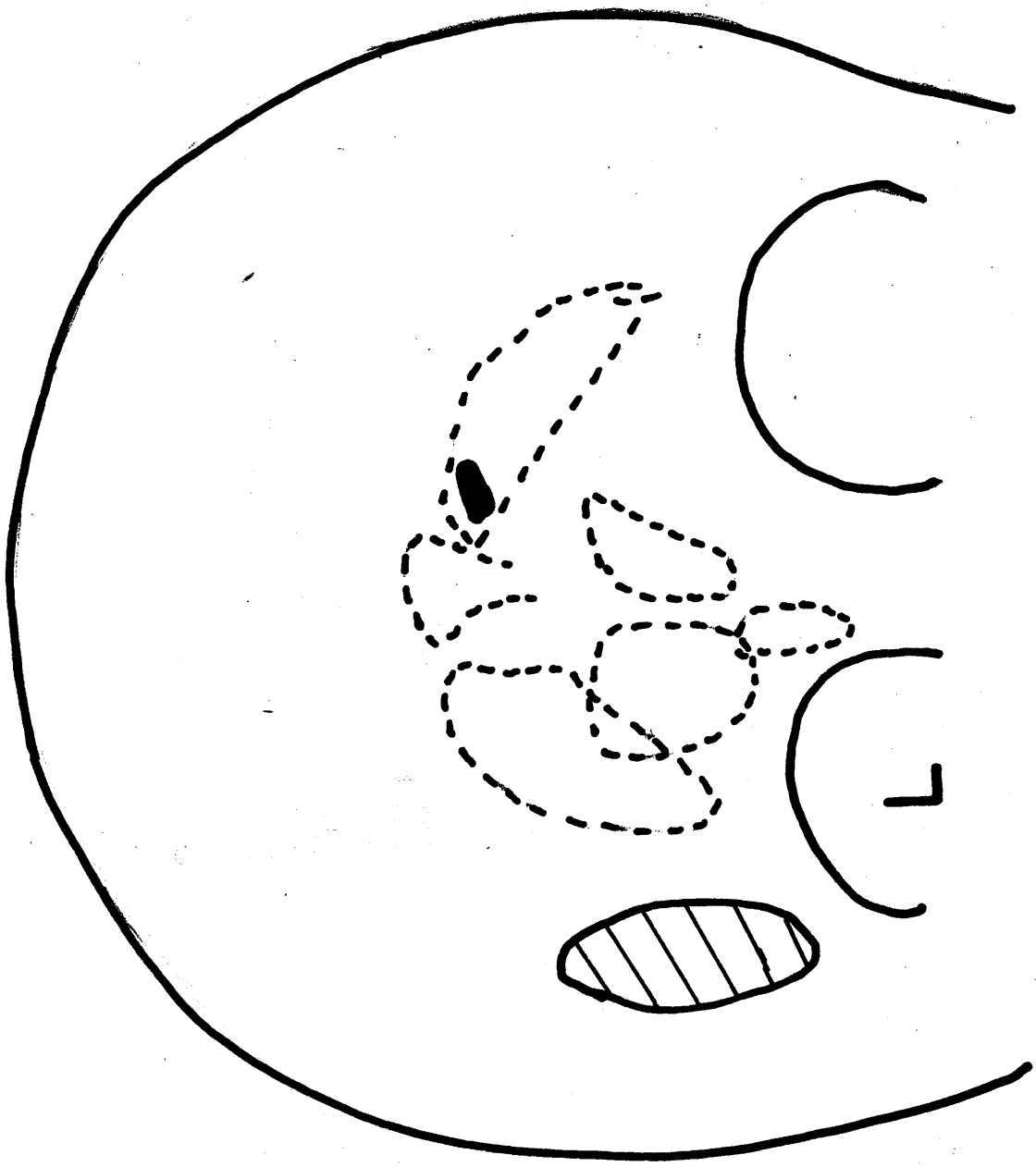


Figure 43.

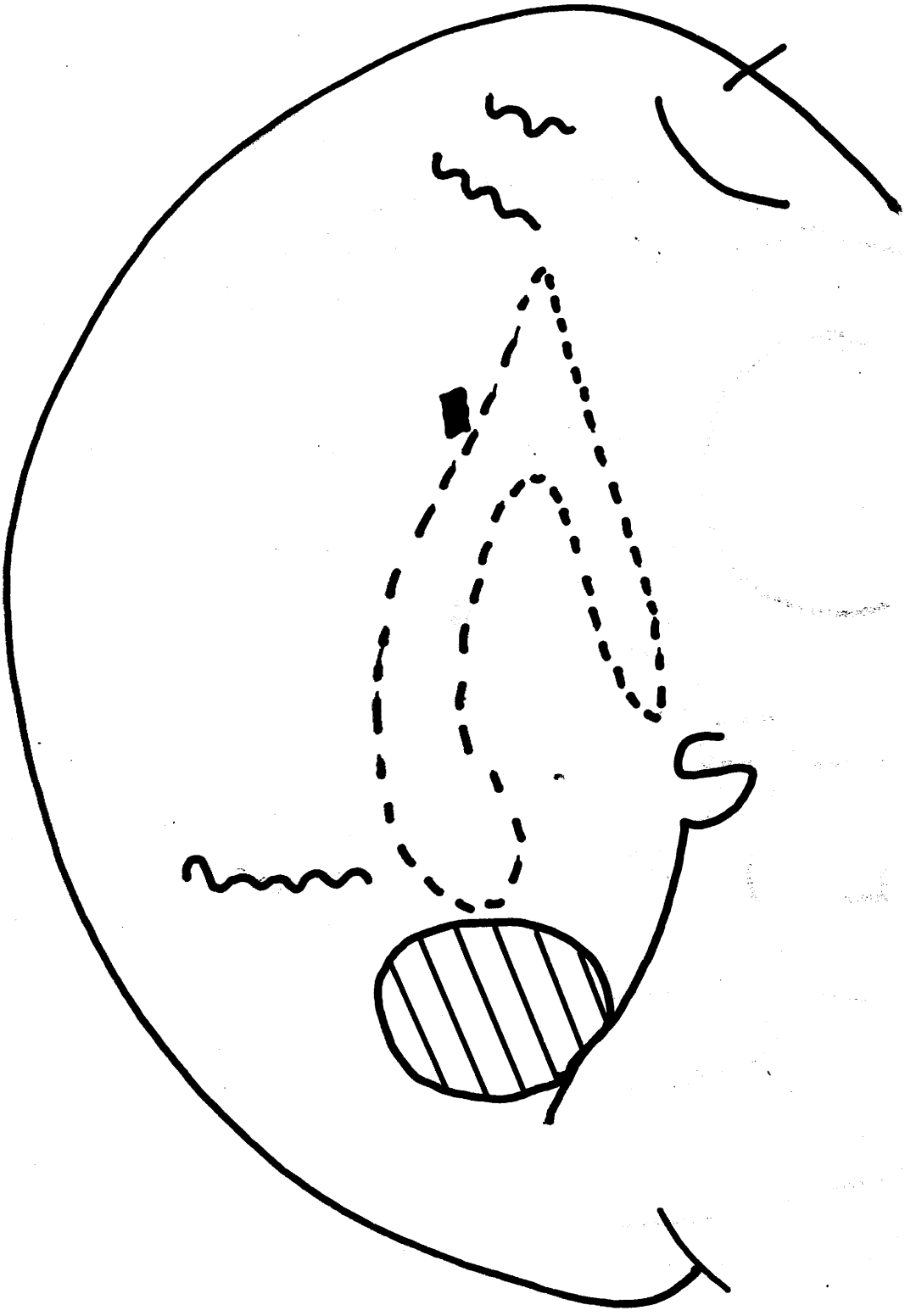


Figure 42.

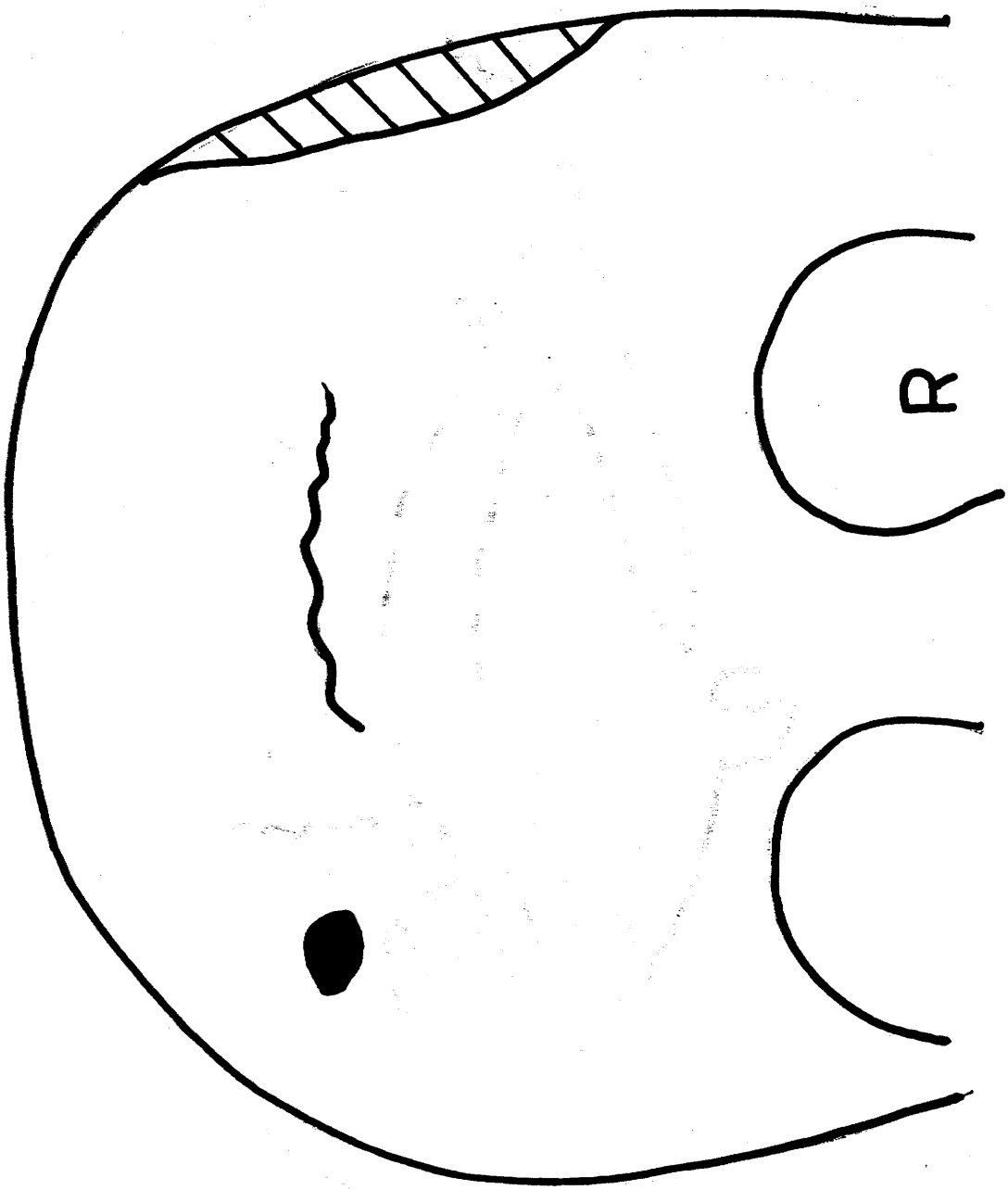


Figure 42.

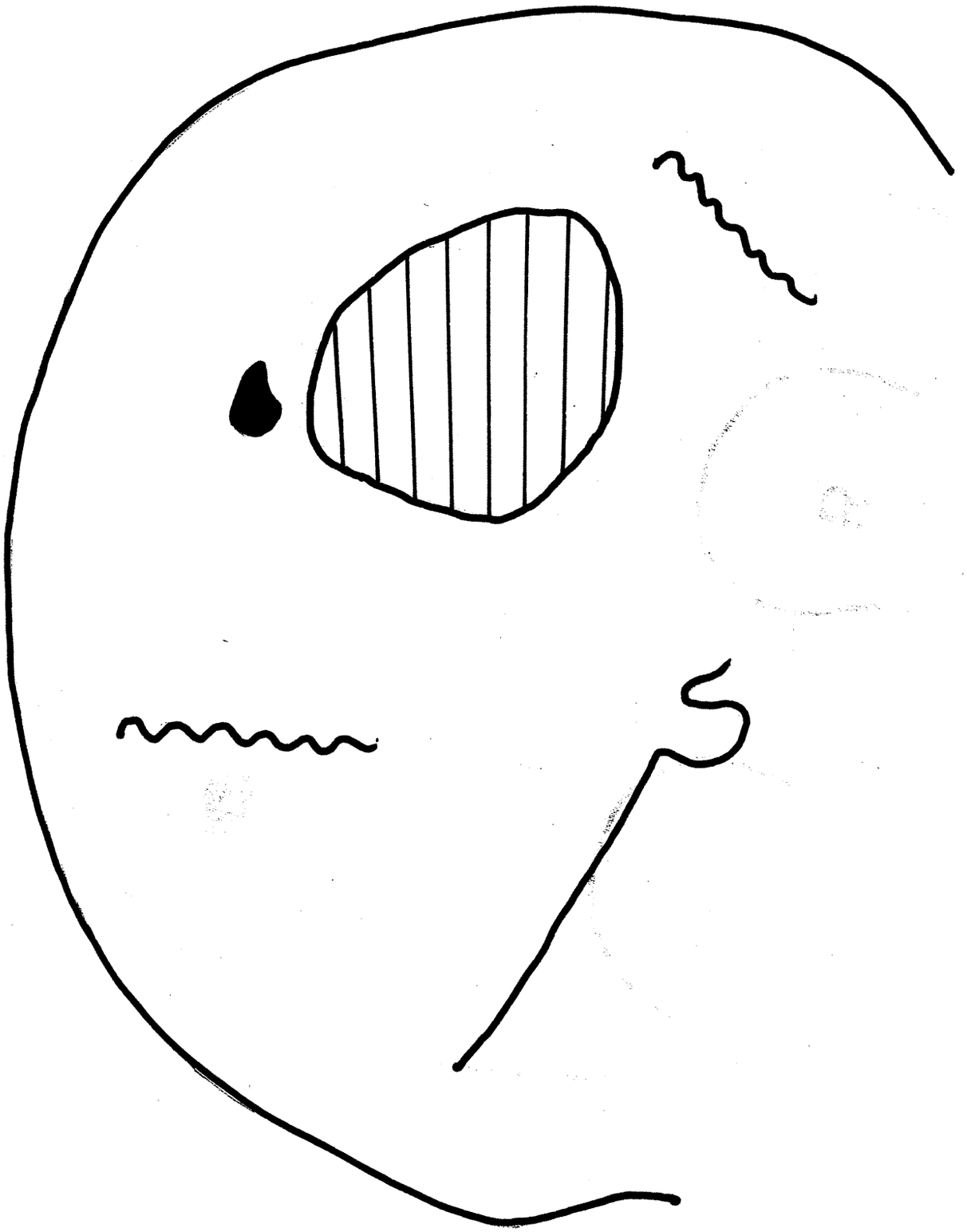


TABLE VIII. ANATOMICAL AND NEUROLOGICAL DETAILS IN 5 CASES IN WHICH THE DOMINOES SCORE HAS FALLEN BY 4 OR MORE POINTS SINCE INJURY.

1	2	3	4	5	6	7	8
Case No.	Description of Wound	P.T.A. R.A.	P.T.A. (days)	A.E.G.	E.E.G.	Traumatic Epilepsy	Neurological Signs
9	R.-L. parietal. Bony perforn. 1 x 0.5 cm. in R. post. par. reg., w. underlying dural tear 1.5 x 0.5 cm. thro' wh. metallic fragmt. has been driven piercing falx to lie in ant. parietal region on L. (Fig. 42). Thro & thro' wound of R. lat. vent. Track re-explored down into L. pariet. lobe at 2nd craniectomy. Area of cortex 1 x 2 cm. resected from surface borders of track in R. parietal lobe.	Few min.	Sev. wks.	-	Slow-wave focus R. temp. parietal area	+	Early stupor. Stormy post-op. course. Severe abdom. injuries. R. lower facial wkness. Wkness R. hand. Impaired 2-pt. discriminatn. & astereognosis R. hand. Posn. sense poor fingers R. hand.
14	L. frontal-R. parietal. Bony perforn. 1 x 1 cm. above & lat. to L. eyebrow, w. underlying dural tear 1 x 1.5 cm. thro' wh. small missile has been indriven, traversing anat. posn. of L. lat. vent. to rest in post. par. reg. just to R. of midline (Fig. 43). Large subd. haemat. (100 c.c.) in ant. fossa over ant. convexity of hemisphere. Very narrow missile canal; wd. not admit finger. At 2nd opn. small portion L. front. lobe resected in wh. bone fragmt. 0.5 x 0.3 x 0.2 cm. was embedded.	0	0	Dilatn. L. lat. vent. w'out Displ. mt.	No paroxysmal activ.	0	Left facial weakness.
16	L. frontal. Accidentally wounded by 0.22 bullet. Entry wnd. 5 cm. above L. ear. Nose of bullet embedded in brain, midline, L. front. reg. near ant. end corp. callosum (Fig. 44). Slit-like tear of dura 1.5 cm. long w. bullet track passing medially & slightly upwards.	0	Sev. hrs.	Ant. horn L. lat. vent. flattnd. MFB lies outside vent. system	Episodic outbursts 3-4 c/s Slow sharp wvs. on overbrthng.	0	Early expressive dysphasia

Figure 46.

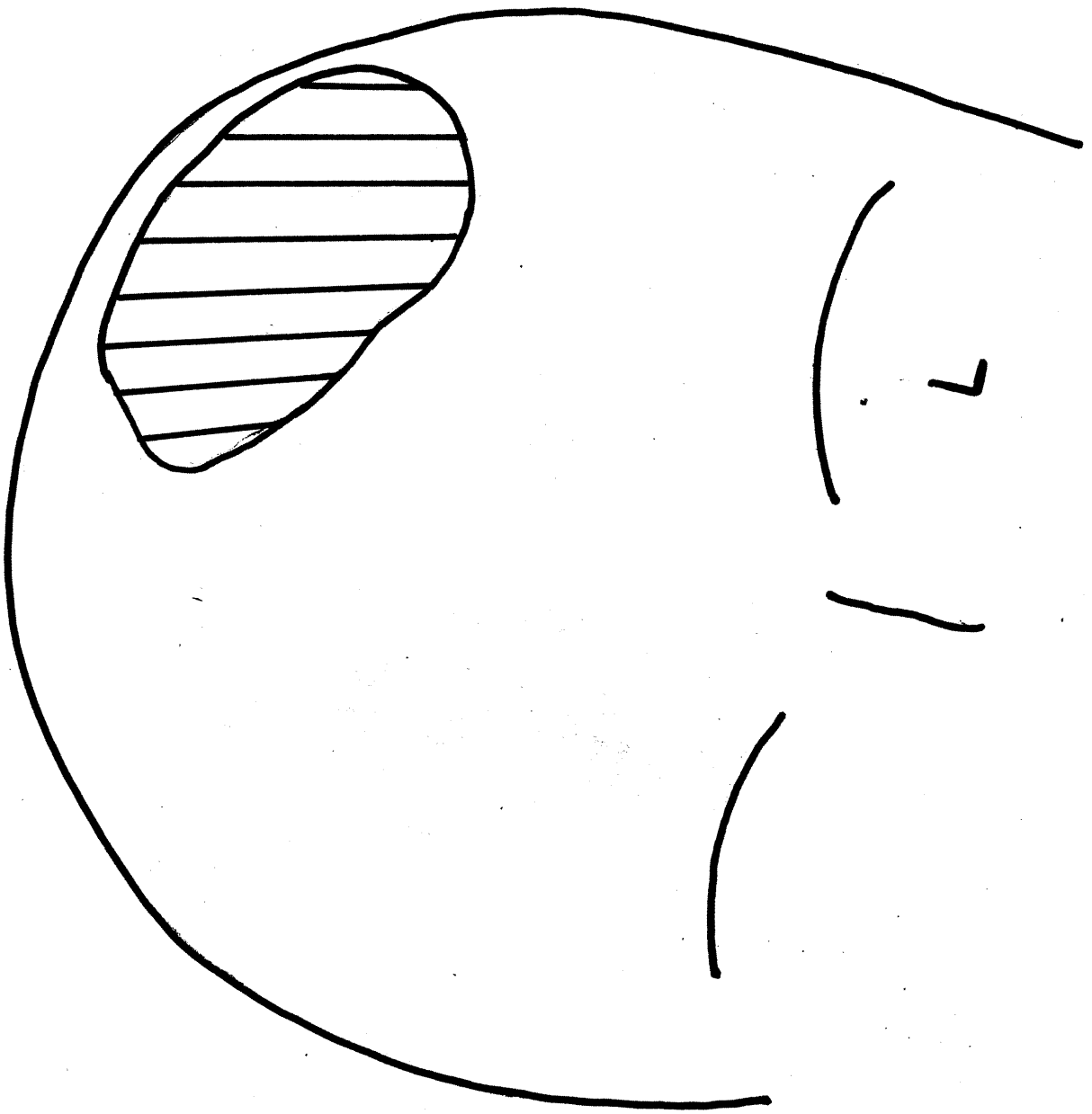


Figure 46.

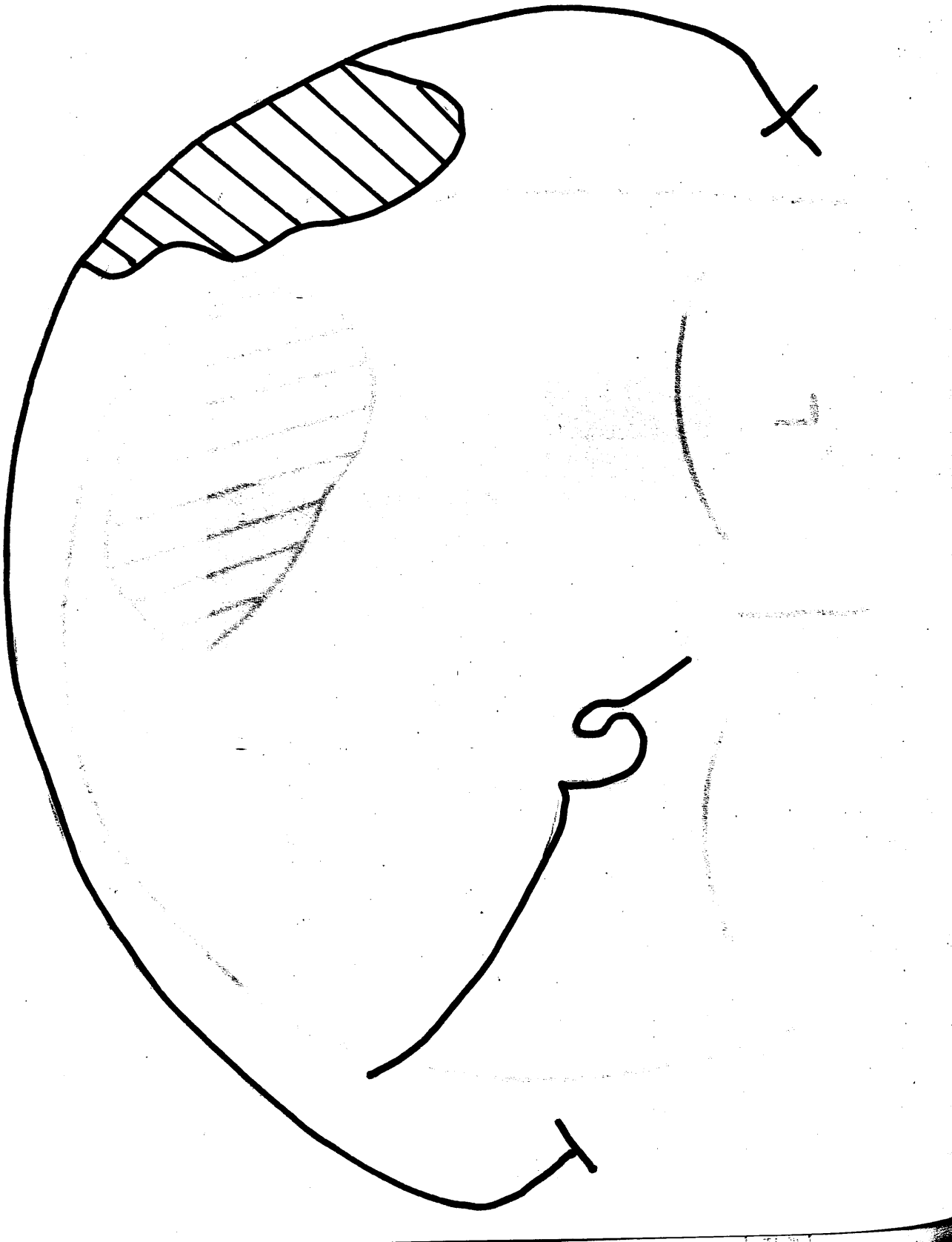
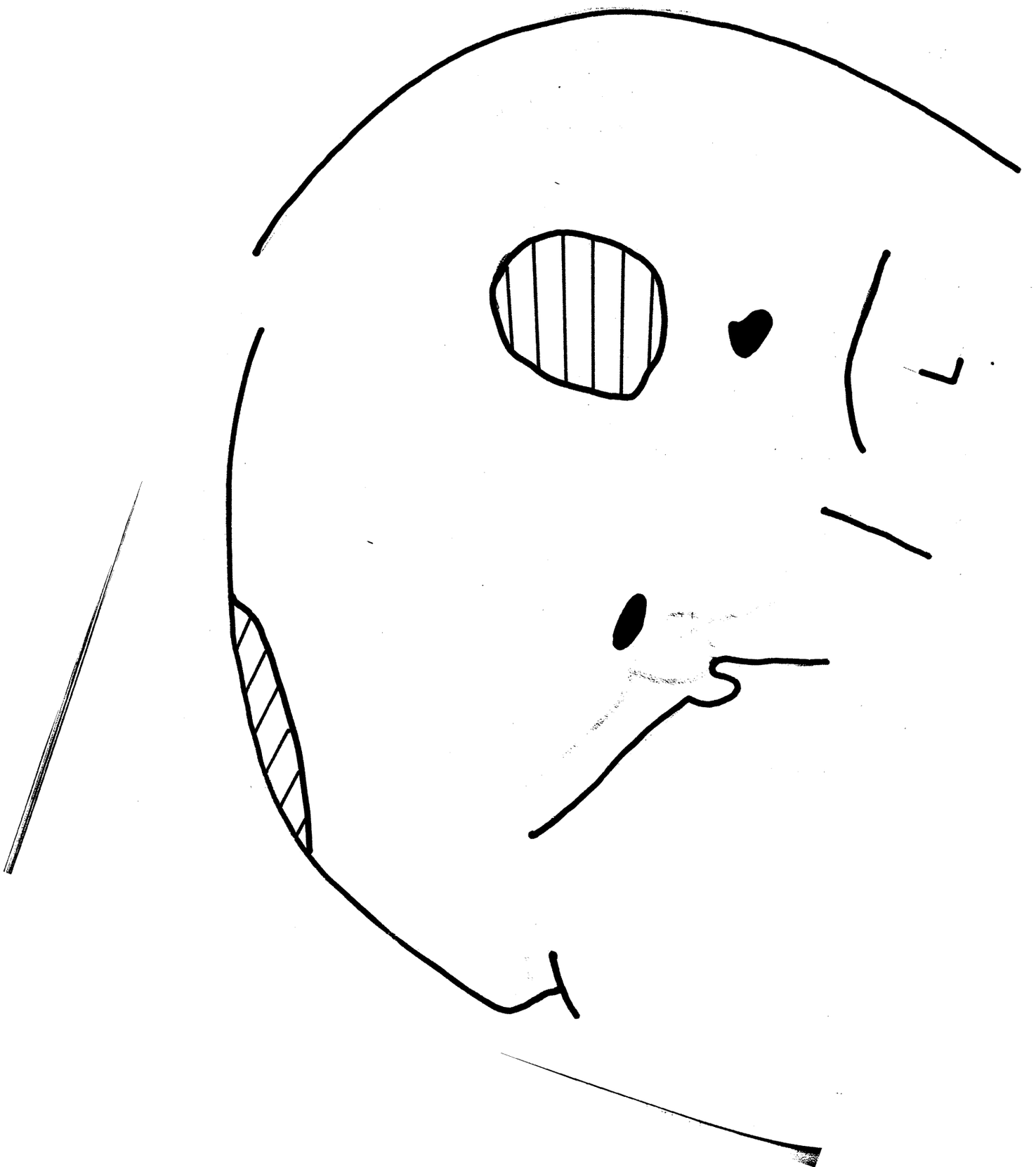


Figure 45.



1	2	3	4	5	6	7	8
38	L. frontal. 2.5 cm. lacern. at hair-line Med.-sized metallic fragmt. indriven downwd. & backwd. towards base of frontal lobe (Fig. 45). Missile track widely debrided & bone fragmts. removed.	0	0	-	Paroxysmal (?)	0	Left hyposmia. R. facial & generalised R.-sided weakness
57	L. parietal. Thro' & thro' scalp wound w. a 6 x 2 cm. gutter-type depressed fr. of parietal bone & underlying dural defect 6 x 1.5 cm. Parietal cortex severely lacerated in this tangential wound & a bone fragmt. driven 4-5 cm. into ant. part of parietal lobe towards the motor strip. Bone fragmt. & liquefiei brain tissue removed. Post-operative skull films (Fig. 46).	3 days	3	-	Mild residual abnorm. on L. & bilat. sharp wave activity	+	Disturbance of body image in early stages (confusion of R. & L. leg. Residual lower R. quadrantanopia, spastic paresis & cortical sensory loss R. leg.

Figure 48.

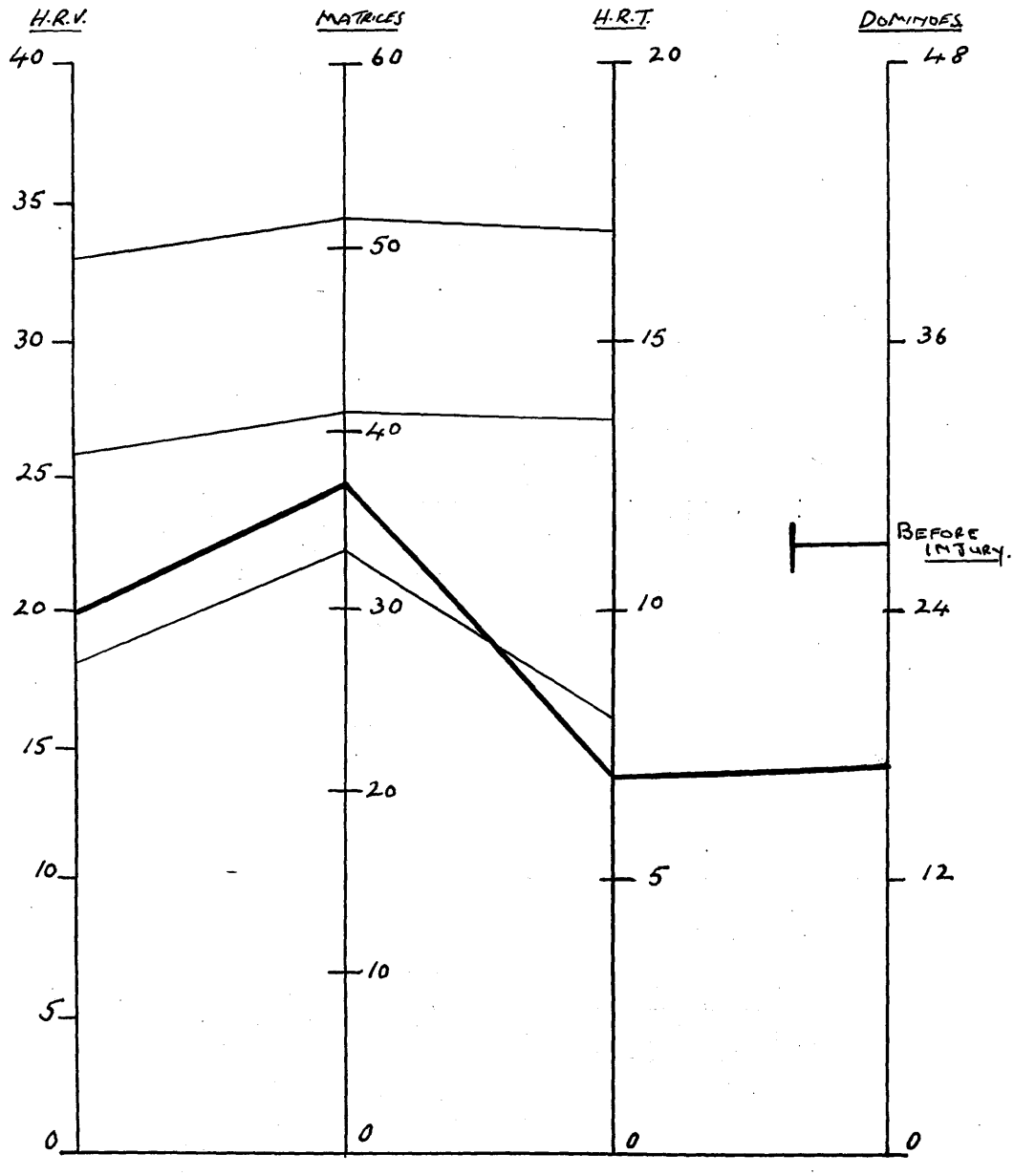
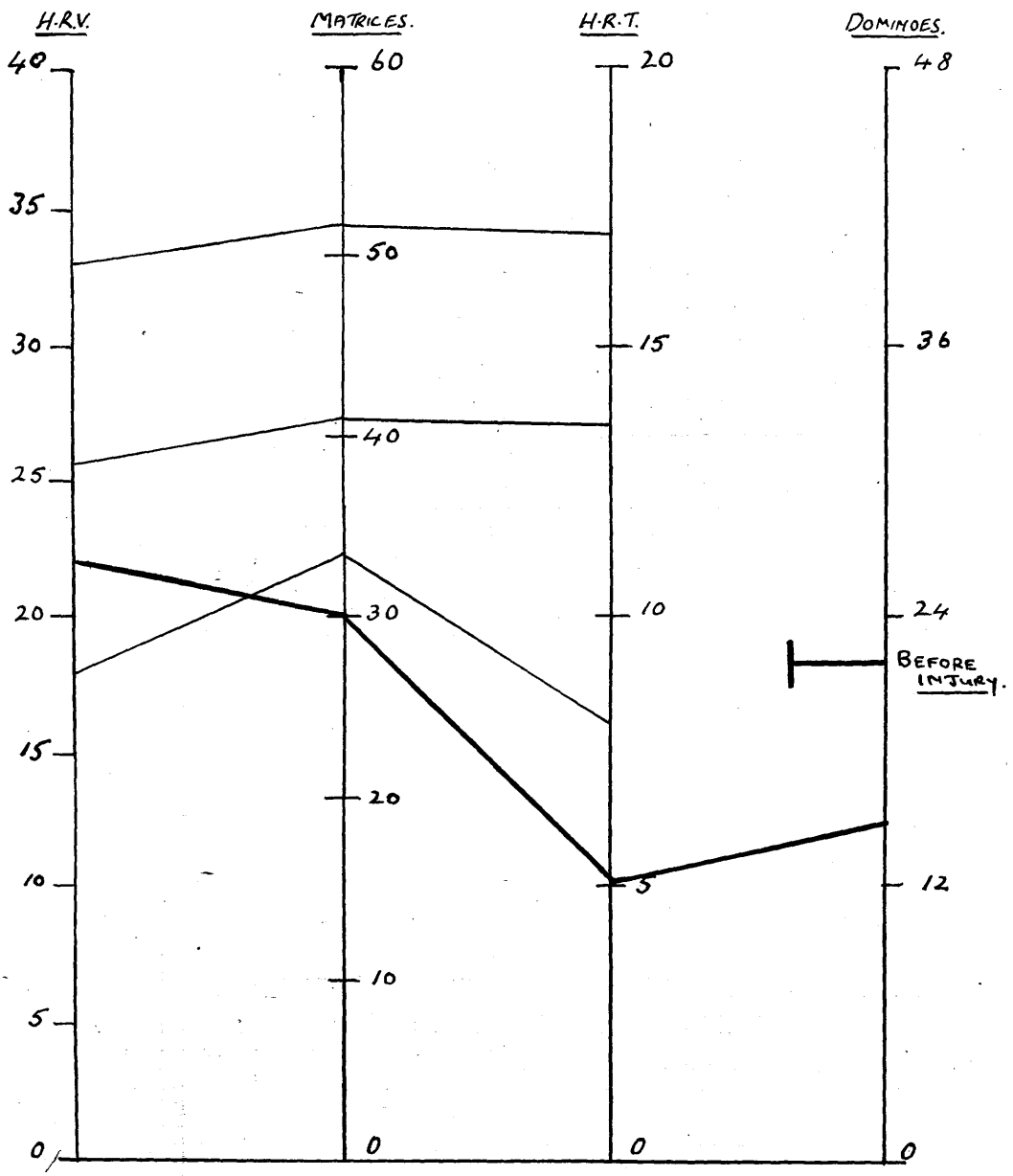

H.R.V.
MATRICES
H.R.T.
DOMINOES
40
35
30
25
20
15
10
5
0
60
50
40
30
20
10
0
20
15
10
5
0
48
36
24
12
0
BEFORE INJURY.

Figure 47.


H.R.V.
MATRICES.
H.R.T.
DOMINOES.
40
35
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48
36
24
12
0
BEFORE INJURY.

Certain points must now be commented upon. In none of the 5 cases was there evidence of an absolute intellectual deficit, although all showed some impairment in intellectual functioning. They were all cases of recent wounding, and the period which had elapsed between wounding and testing varied from 2 to 5 months. It was apparent in the frontal lobe cases (14, 16 and 38), and in other frontal lobe cases in the series tested within a few weeks of injury, that the response to mental testing was often erratic and fluctuating. In patients with recent frontal lobe injury more than any other, the necessity for taking them over their mistakes on the Matrices was most often felt, because they seemed so often to do difficult examples correctly while failing on easy ones.

The position with regard to the two parietal lobe cases (9 and 57) was rather different. In both, a spontaneous history was obtained, in one case of difficulty in doing sums since injury, and in the other of forming and recognising figures. The drop in the Dominoes score was respectively 7 and 10 points, whilein both cases on the Matrices they seemed to be functioning more or less within their normal intellectual range. Mental testing charts are reproduced for both these cases (Figs. 47 and 48).

It became apparent during the course of the investigation that the Dominoes Test was an efficient indicator of

dyscalculia. In this test not only has the relation between groups of dots to be recognised, but in performing the test the number of dots in separate patterns has to be counted and retained. It seemed clear, therefore, that certainly in Case 57, in whom there was quite conclusive evidence of a disturbance of figure-symbolism, the fall in the Dominoes score was due to this. The evidence in Case 9 is less conclusive. In this case the patient was disturbed emotionally when tested, but the evidence for a degree of dyscalculia being present is certainly suggestive, especially in view of the fall in the Dominoes score taken in conjunction with the spontaneous history. These cases with dyscalculia will be dealt with more fully when the dysphasic cases are discussed.

(b) Other cases with doubtful impairment in intellectual functioning.

The details of mental testing, with relevant comments on the 10 cases in this group, are given in Table IX, while the anatomical and neurological details are given in Table X.

TABLE IX. DETAILS OF MENTAL TESTING, OTHER INFORMATION AND COMMENT IN 10 CASES WITH DOUBTFUL IMPAIRMENT IN INTELLECTUAL FUNCTIONING.

1	2	3	4	5	6	7	8	9
Case & Index Nos.	H.R.V.	H.R.T.	Matrices Score	Matrices S.G.	Dominoes Score	Dominoes S.G.	Other Information	Comment
2 (203)	26	6	28	IV	-	-	Matrices score corrected to 36 (S.G. IV). 2. 10.44 (W.R.Reynell) Matrices = 35 (1st try): 44 (2nd try). Never very bright intellectually, failed Junior Oxford. Left school at 15; junior clerk. Gross frontal lobe personality change. Restless & distractable.	Basic scores on problem-solving tests are low. Has however functioned within his presumed intellectual range on Matrices at some time since injury. Difficulty in schooling. Present distractability may be factor interfering with adequate test performance Difficult to be dogmatic about absolute intellectual loss, but int. funct. certainly impaired.
11 (893)	37	15	42	III-	20	IV	Left school at 14; semi-skilled job. Always a good reader	Scores on problem-solving tests are low compared w. vocab. level reached, esp Dominoes. ?Deteriorating.
22 (120)	30	14	39	III-	19	IV	Corrected Matrices score to 44 (S.G. III). Left school at 14; semi-skilled jobs.	Probably functioning with in his normal intellectua range, but Dominoes score low.

1	2	3	4	5	6	7	8	9
29 (585)	31	5	32	IV	30	III+	Corrected Matrices score to 41 (S.G. III-). Left school at 14; good scholar	Scores on Matrices & H.R.T. indicate deterioration. Surprisingly high score on Dominoes
30 (132)	27	4	33	IV	19	IV	Corrected score on Matrices to 37 (S.G.IV).	Scores on all problem-solving tests are down compared with vocabulary level. ?Deterioration.
36 (457)	26	7	41	III-	15	IV	24.5.44 Matrices 37 (S.G.III-) "Below average at school. Vocabulary poor & arithmetic v. poor." (W.R.Reynell)	Matrices score consistent with vocabulary level. Low on H.R.T. and Dominoes.
43 (822)	31	8	30	IV	15	IV	Cooperation poor. Melancholic.	Although scores on all problem-solving tests are consistently low compared w. vocab. score, this pt's mental state was such that no conclusions could be drawn regarding intell. deterioration.
48 (702)	27	13	45	III+	22	IV	Left school at 14; average. Semi-skilled jobs	Dominoes score low.
51 (713)	25	9	40	III-	17	IV	29.3.45 Matrices 38,(S.G.III-) 10.7.45 " 41 (S.G. III-) (W.R.Reynell). Left school at 14; average. Labouring jobs.	Dominoes score low.
64	37	8	33	IV	29	III+	Corrected Matrices score to 39 (S.G. III-). Severe epilepsy. Re-test 19.10.53 foll. cortical excision, H.R.V. 35, H.R.T. 14, Matr. 40 (corr. to 47 - S.G.III- to III+, Dominoes 30, S.G.III+	Matrices & H.R.T. scores would indicate deterioratn. Dominoes score high. Improvement in performance on Matrices & H.R.T. following cortical excision is of interest.

Figure 52.

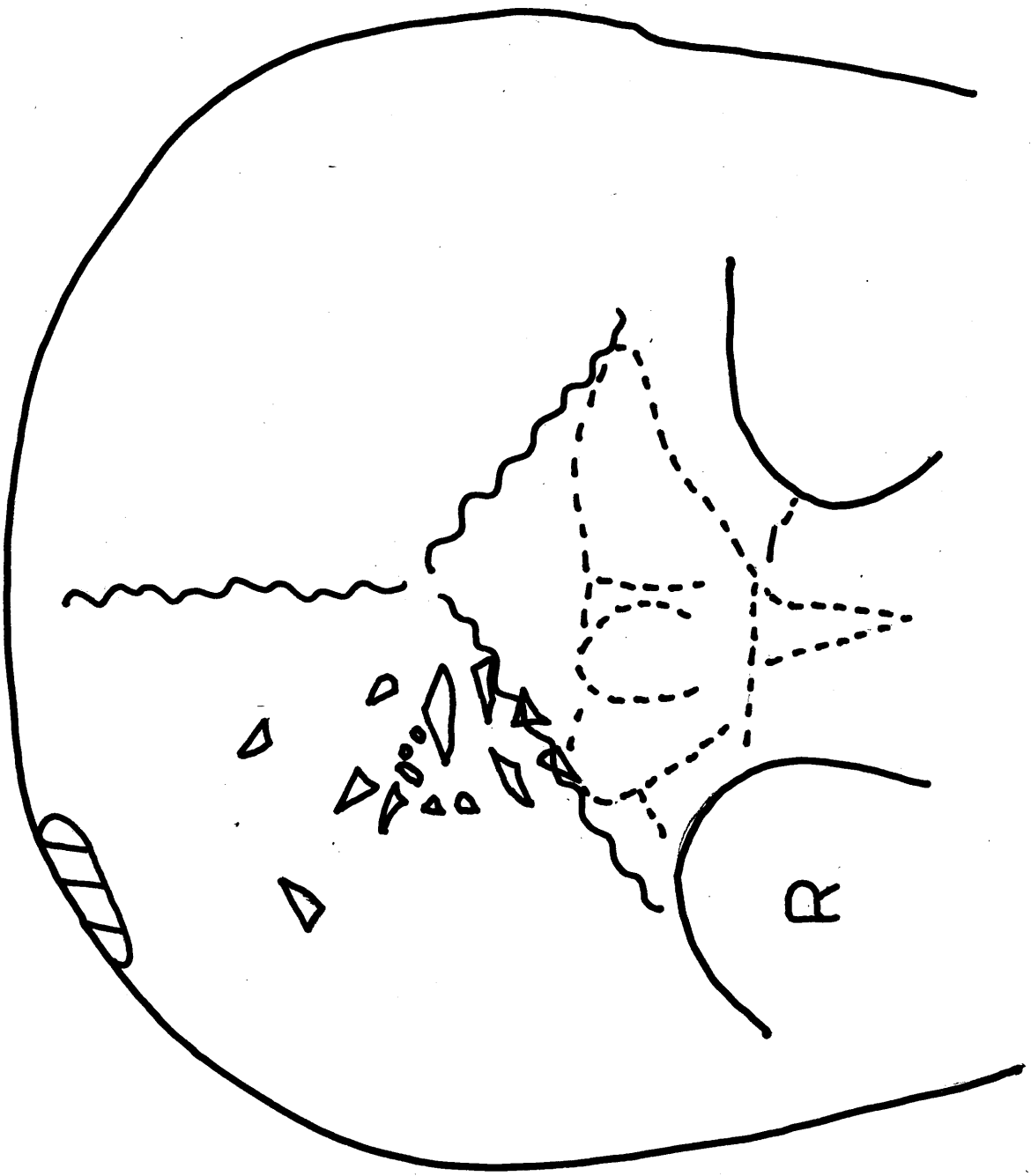


Figure 52.

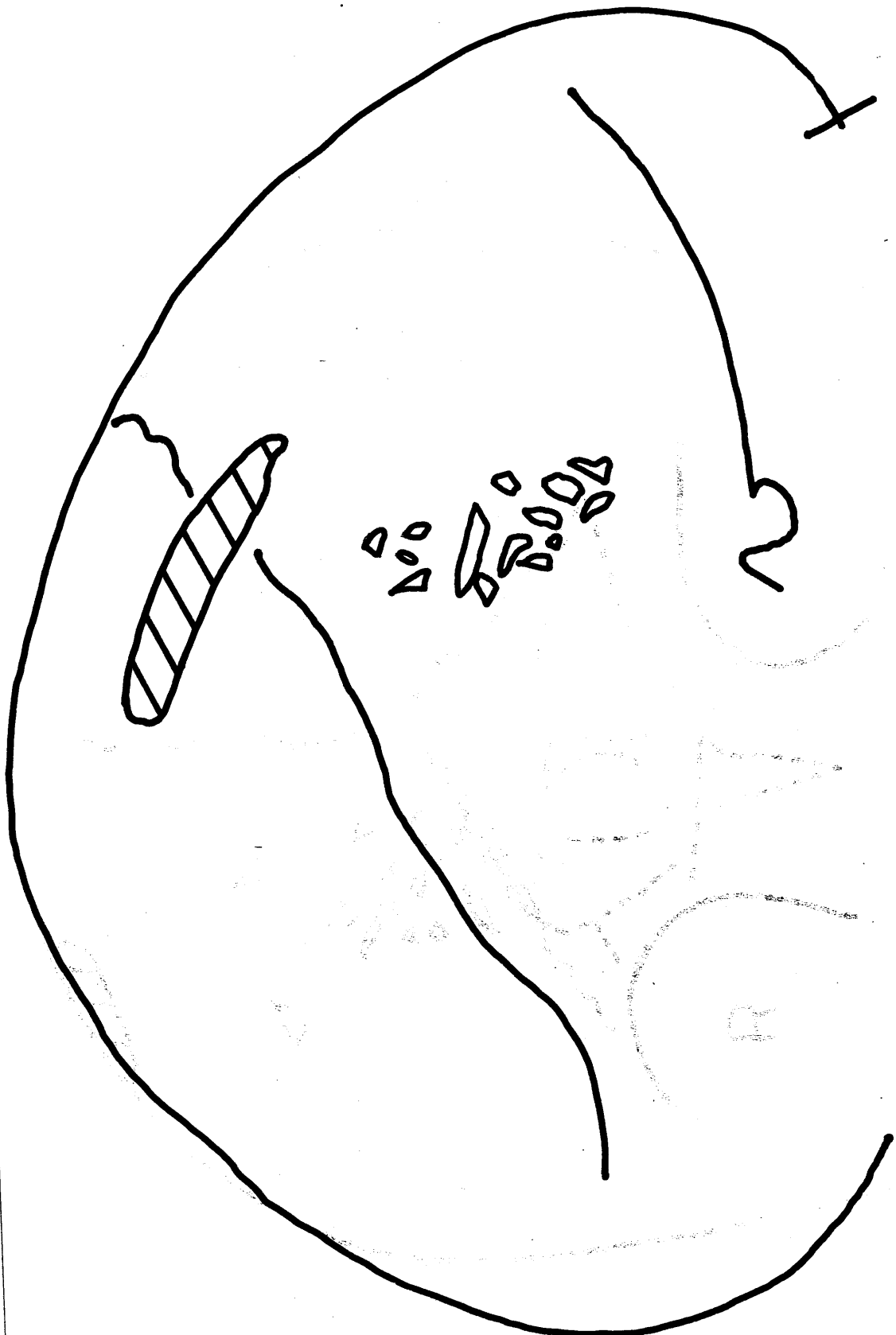


Figure 51.

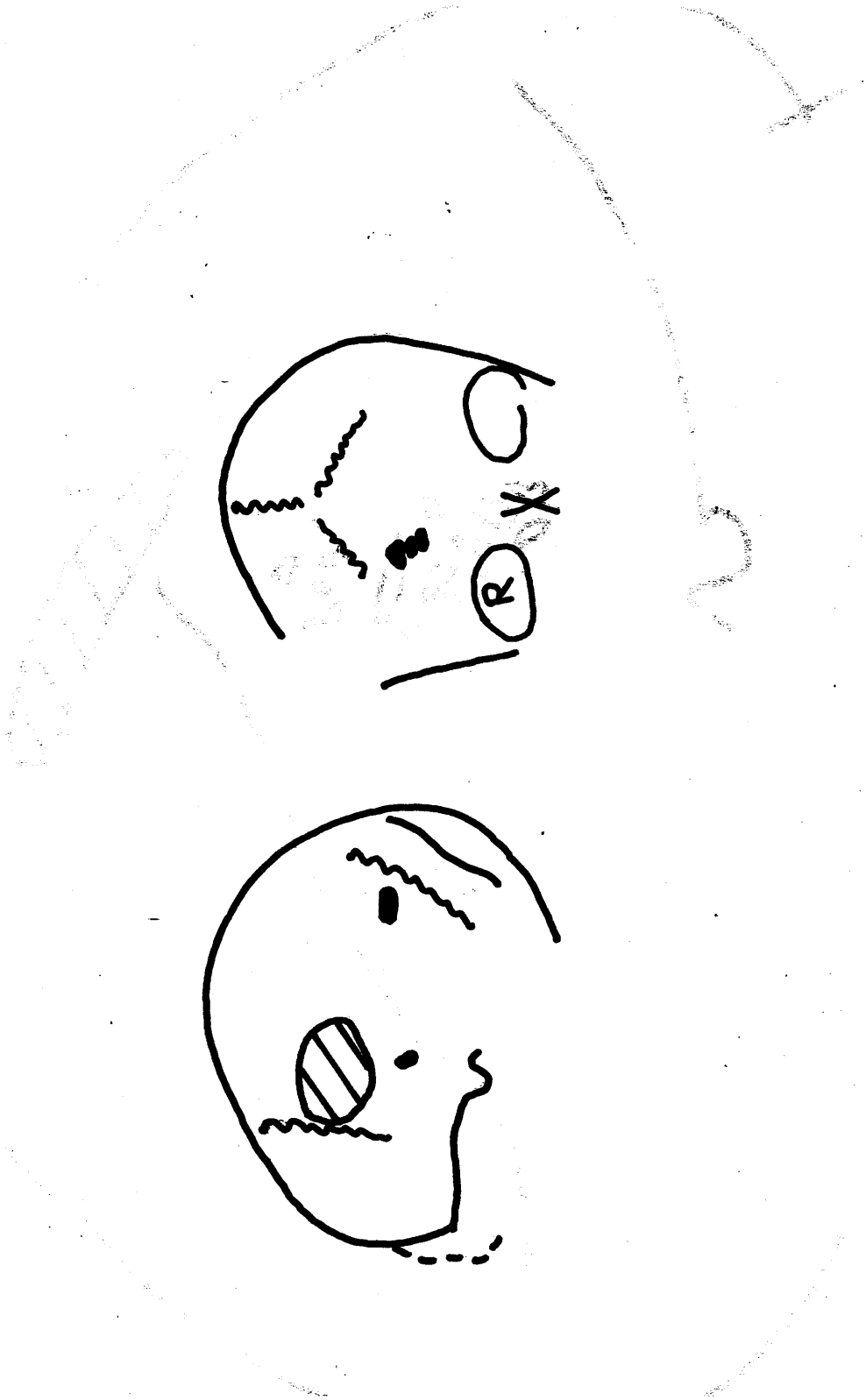


Figure 50.

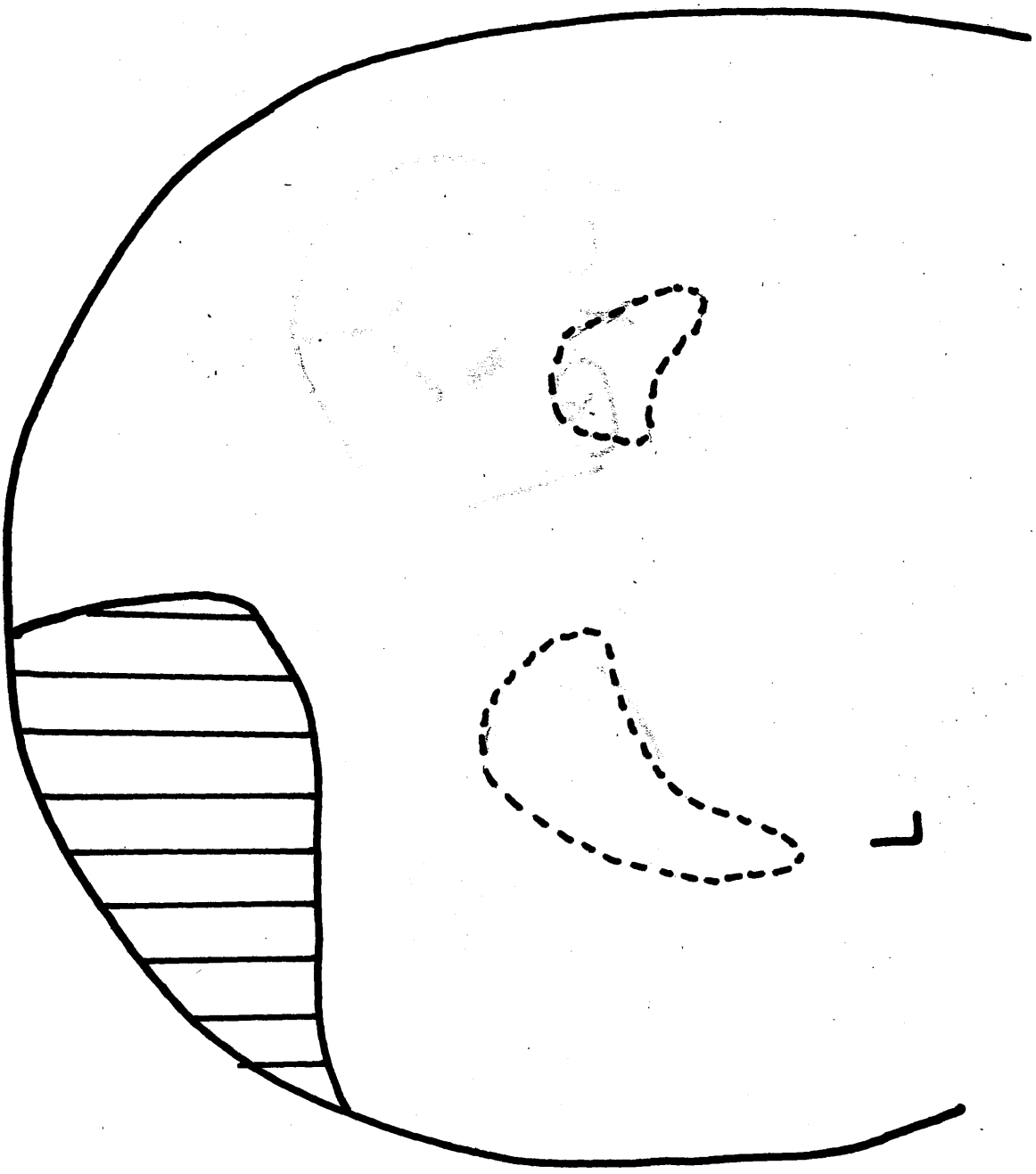


Figure 50.

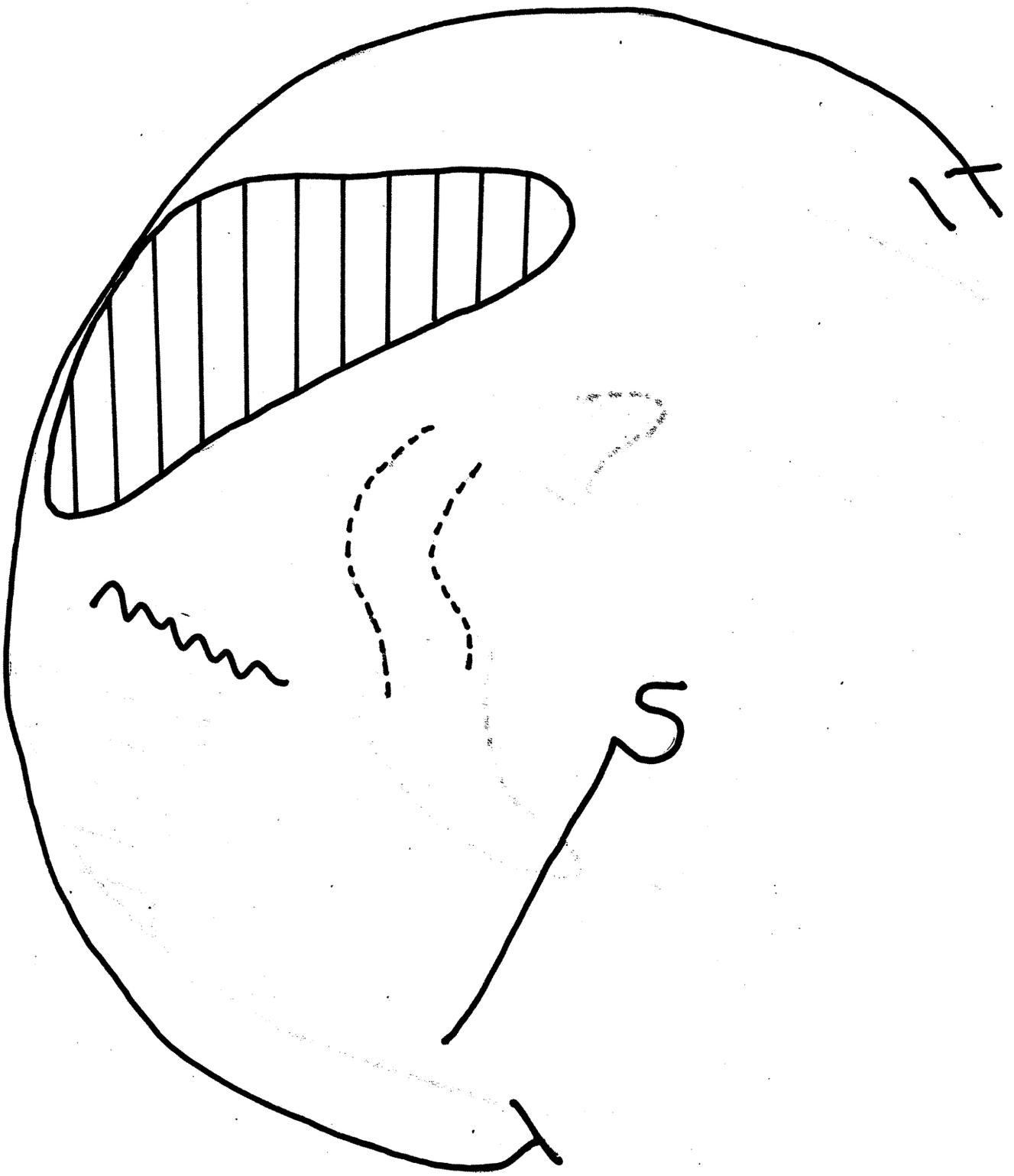


Figure 49.

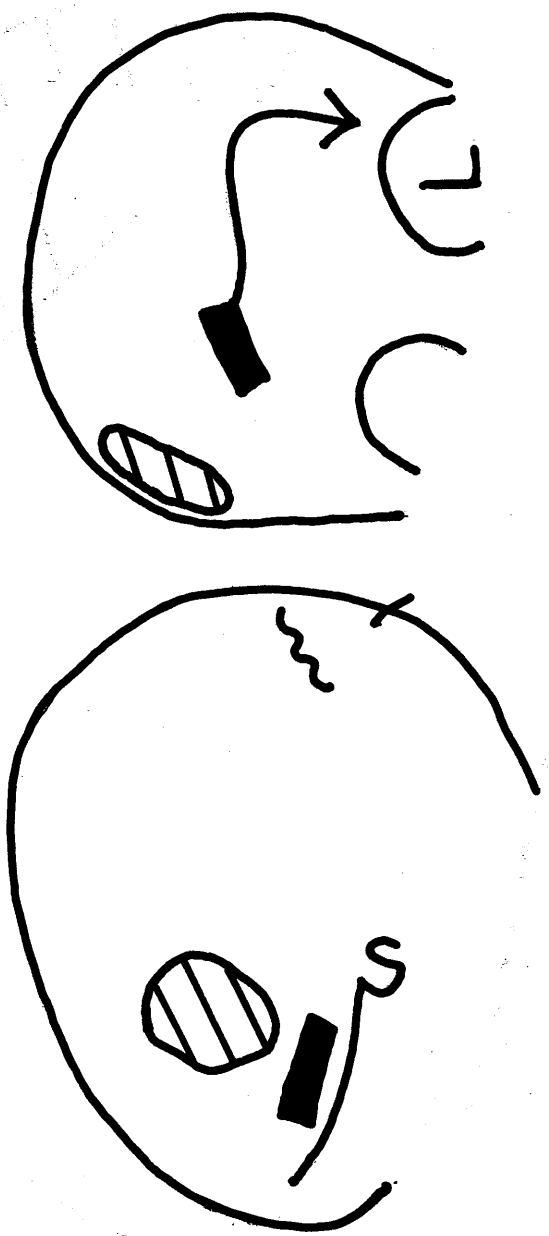


TABLE X. ANATOMICAL AND NEUROLOGICAL DETAILS IN 10 CASES WITH DOUBTFUL IMPAIRMENT IN INTELLECTUAL FUNCTIONING.

1	2	3	4	5	6	7	8
Case No.	Description of Wound	R.A.	P.T.A. (days)	A.E.G.	E.E.G.	Traum. Ep.	Neurological Signs
2	R. frontal. Bullet 3 x 1 x 1 cm. to depth of 6 cm. downwards & forwards from bone defect 2 cm. in diam. MFB eventually found its way to floor of L. ant. fossa, presumably by passing acr. subd. space on under-surface of frontal lobes, from where it was extracted (Fig. 49).	-	-	-	High voltage 2c/s waves from region of bone defect (1944)	0	Early L. hemiparesis. Apathetic & disorientated in early weeks. Not reported as fully orientated until 6 weeks after injury.
11	L. parietal. Thro' & thro' wnd. midline L. occip. - L. pariet. making skull gutter 5 cm. long. Underlying brain guttered also along falx, also to 5 cm. Few large bone fragmts. indriven. Bone chips & necrotic brain removed (Fig. 50).	Few mins.	Few mins.	Dilatn. L. lat. vent. - pushed towds. skull defect	Very abnormal	+	R. hemiplegia, arm more than leg.
22	R. frontal & R. occipital. Post. frontal wnd. from wh. blood clot, lacerated brain & bone fragmts. & large metal fragmts. were removed. Ventric. penetratn. & deeper metal fragmts. removed fr. region of trigone where choroid plexus was seen. Cavity left 4 cm. long x 2 cm. wide x 6 cm. deep. Post-op. X-rays showed 2 MFBs indriven slightly below the defect transventricularly & a further MFB driven posteriorly into R. occip. lobe (Fig. 51)	0	Few hrs.	-	-	+	Unaware of L. side of body in early stages. L. hemiplegia. L. hemianaesthesia, excluding face. L. lower quadrantanopia.
29	R. frontal. Large amt. destructn. white matter front. & par. regions - "3 fingers in wnd. & went forwd. beyond length 1 finger." Bone fragmt., clot, necrotic brain escapd. under pressre. & vent. fluid welled into wnd. Many indriven bone fragmts. (Fig. 52)	0	4	-	-	+	L. spastic hemiparesis. L. hemihypoaesthesia. Astereognosis L. hand.

Figure 57.

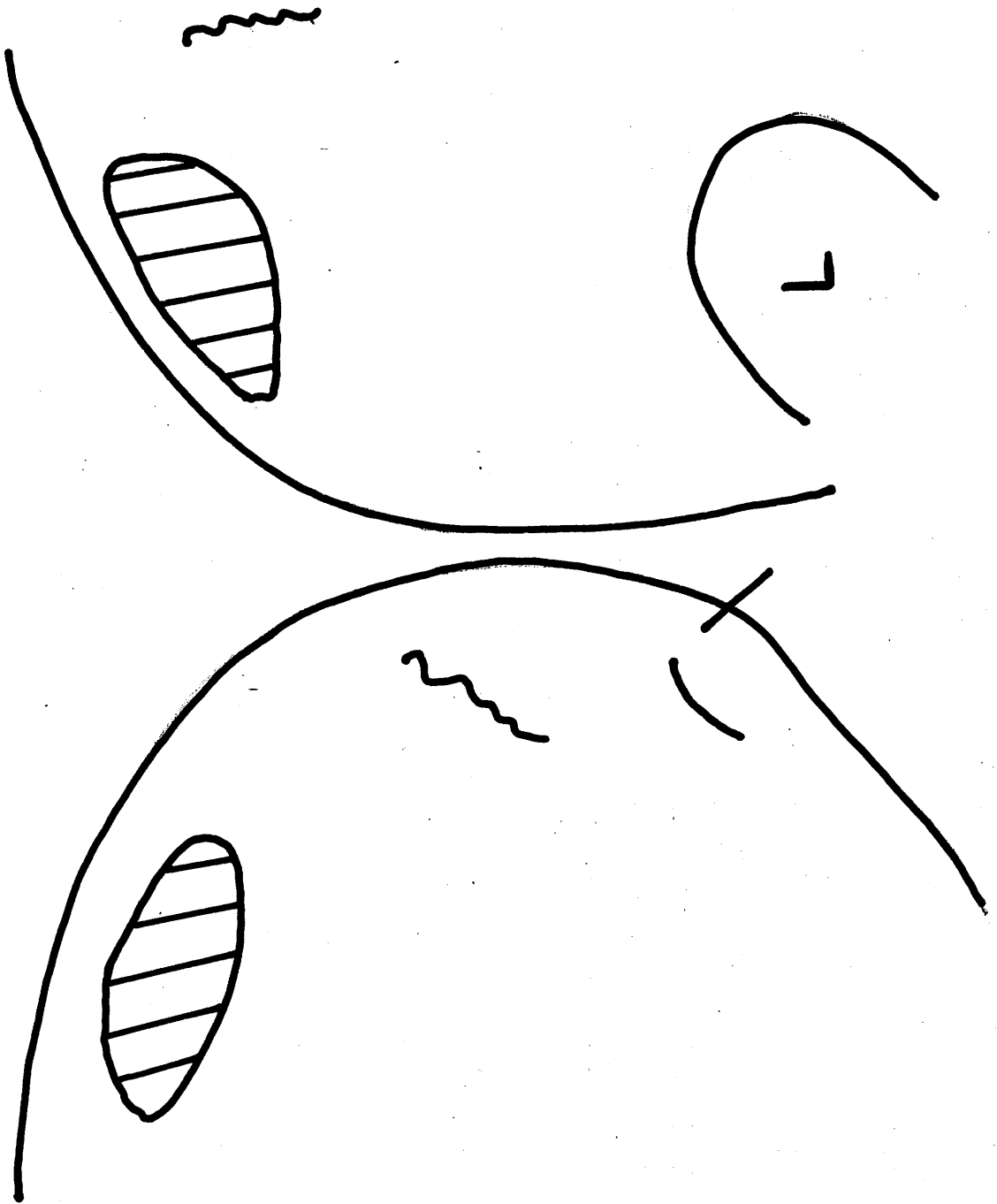


Figure 56.

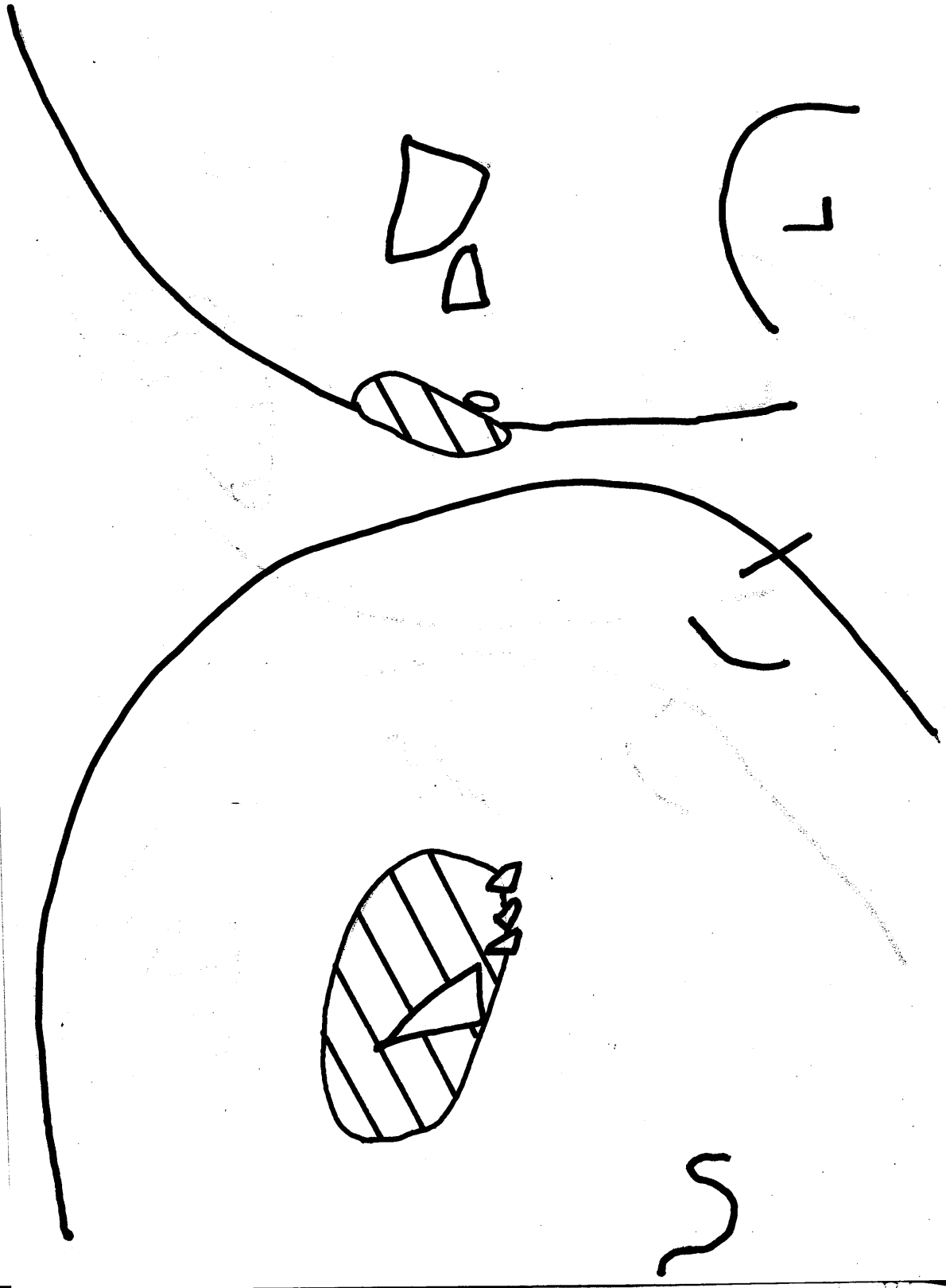


Figure 55.

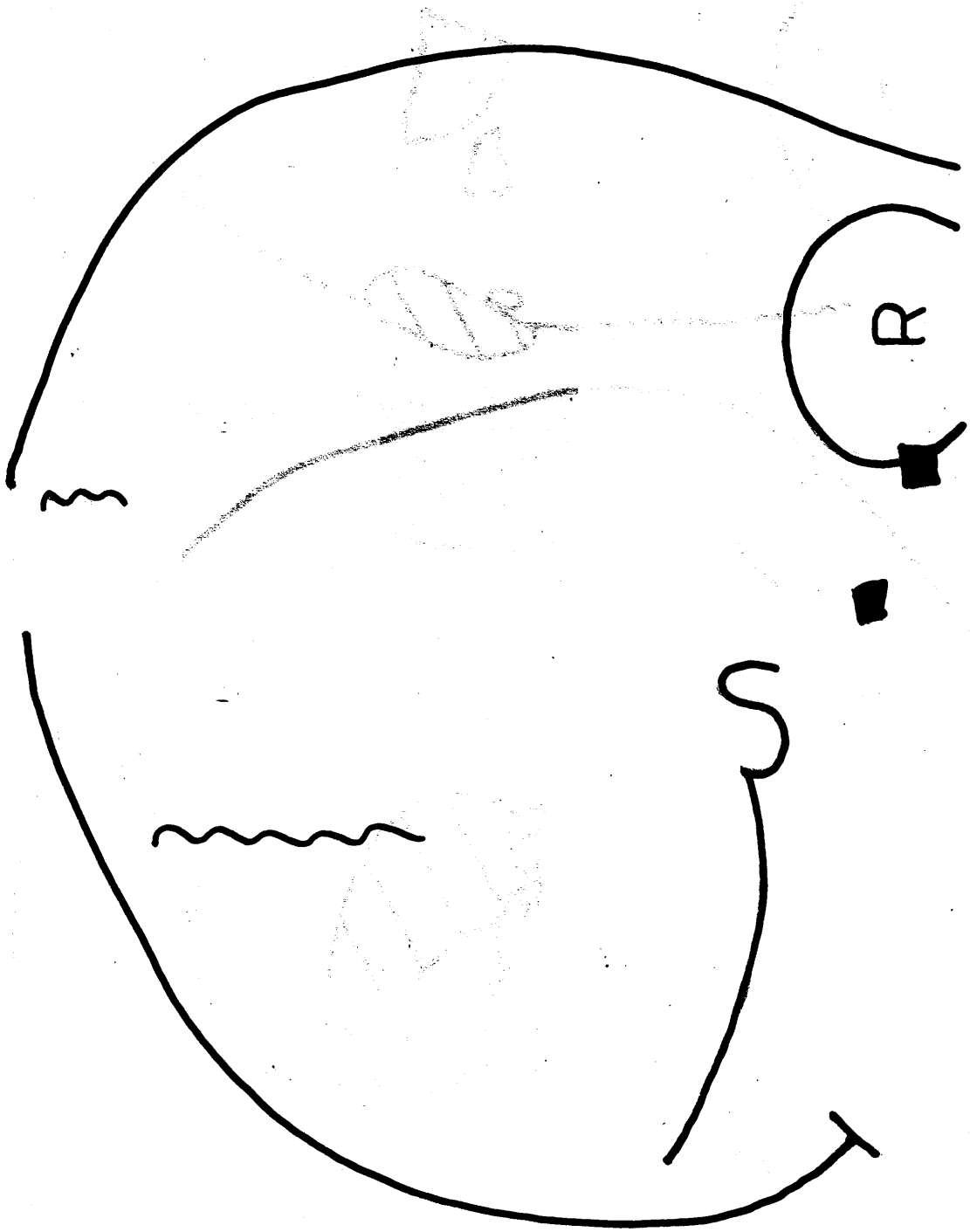


Figure 54.

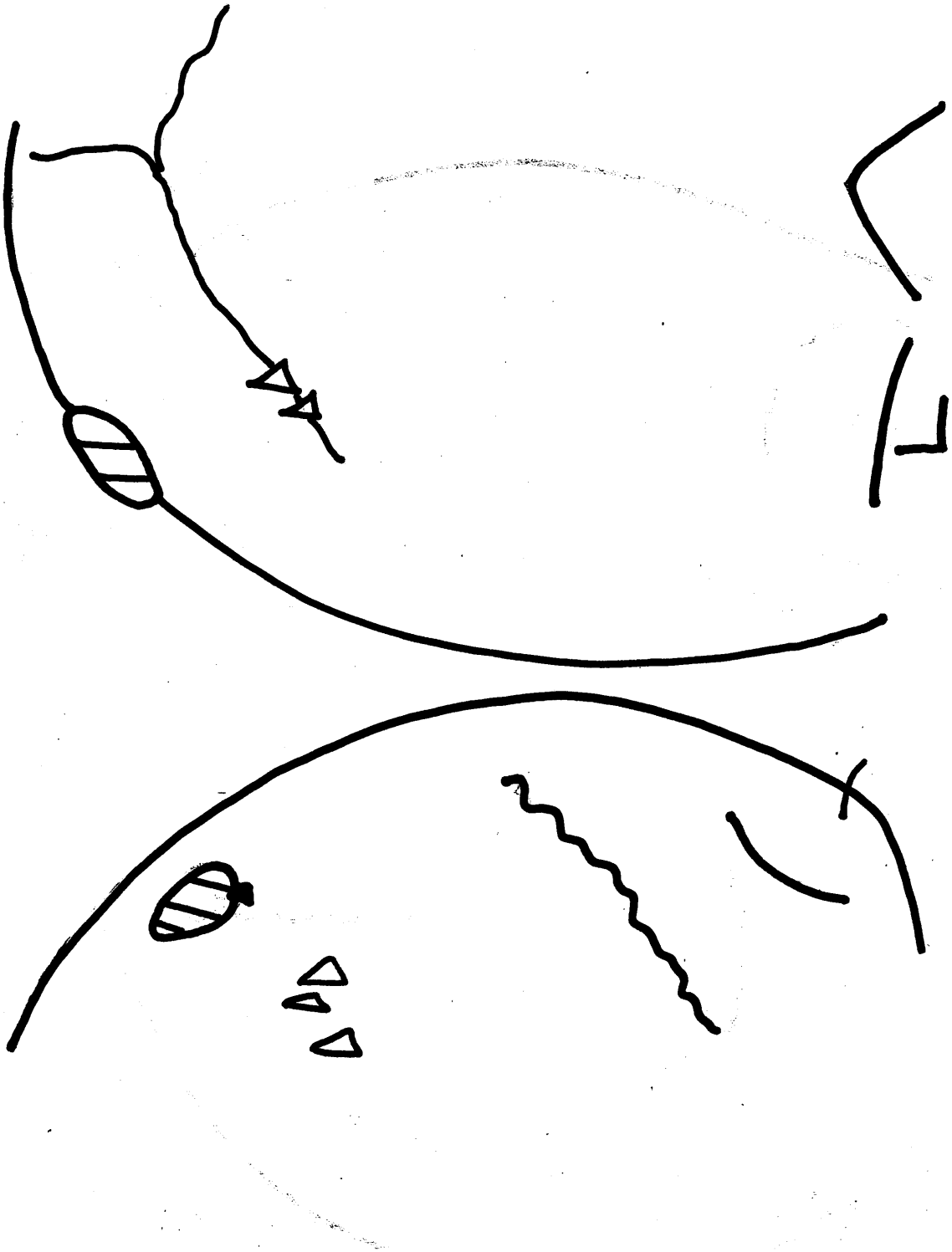
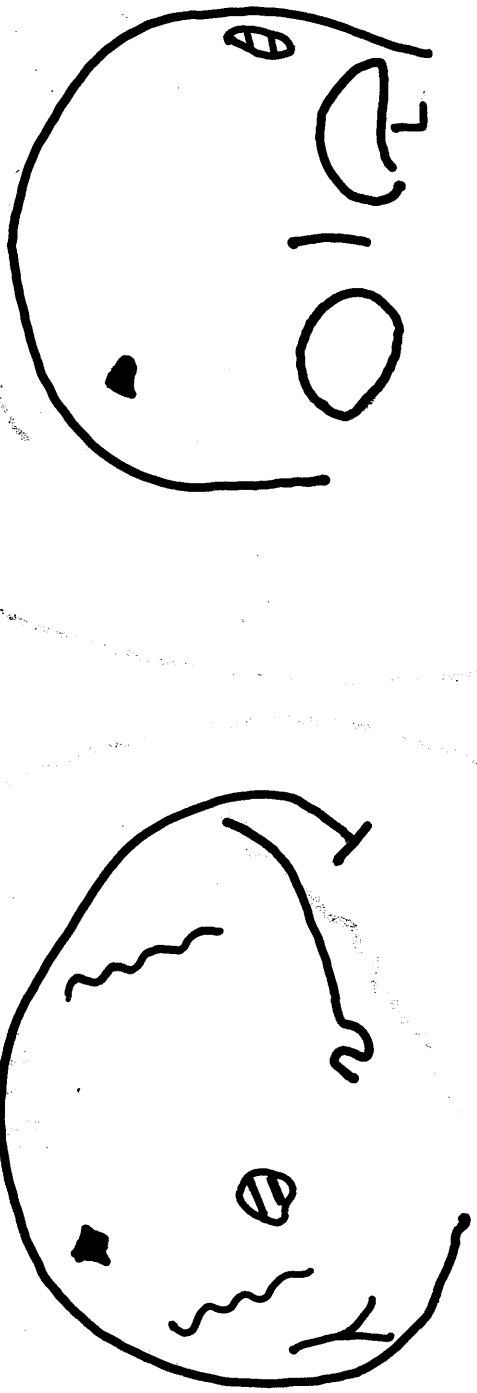


Figure 53.



1	2	3	4	5	6	7	8
30	L.-R. parietal. Bone defect 2 x 1.5 cm.L. postero-infer. pariet., MFB indriven to lie in postero-super. parietal region R. side (Fig. 53). Bone fragmts. indriven to depth of 4 cm. removed at operation.	-	-	-	Paroxysmal	+	Early dysphasia & catatonia. Residual R. lower quadrantanopia
36	L. parietal. Cluster of bone fragmts. indriven about 2.5 cm. into L. parietal lobe. Scattered MFB in scalp (Fig. 54)	Few secs.	10 min	Some dilatn underlying indrvn frgmts	Paroxysmal	+	-
43	R. temporal. MFB embedded in R. petrous temporal. The dura was torn & the brain ?bruised (Fig. 55).	Few mins.	1	-	Focal abnormality	0	Early L. facial paresis & paresis L. arm. Nystagmus. Nerve deafness R. ear.
48	L. parietal. Skull defect 4 x 2 cm. mid-anterior pariet. region. Large superficial bone fragmts. & necrosed cerebral tiss. removed. 2 wide tracks passing inwds. & sl. downwds. one behind other. Ant. slightly larger tapered down to depth of 5-6 cm., its superficial diam. = 3 cm. Post. track 2cm. acr. x 3 cm. deep (Fig. 56) 4 cm.	0	10	-	Paroxysmal	+	Severe early dysphasia. R. facial palsy. R. hemiparesis & hemianaesthesia.
51	L. parietal. Laceratn. dura & brain/acr. Loose bone fragmts. removed. No deep bone fragmts. but 3 tracks, 1 downwds. & backwds., 1 downwds. & forwds. & 1 downwds. & medially to reach falx; all about 5 cm. in depth (Fig. 57)	Few secs.	10 mins.	-	Focal dysrhythmia	+	Early paraphasic errors in spontaneous speech & impairmt. of comprehension. Numbness R. side of body. R. hemiparesis (sl.), persisting.

Figure 58.

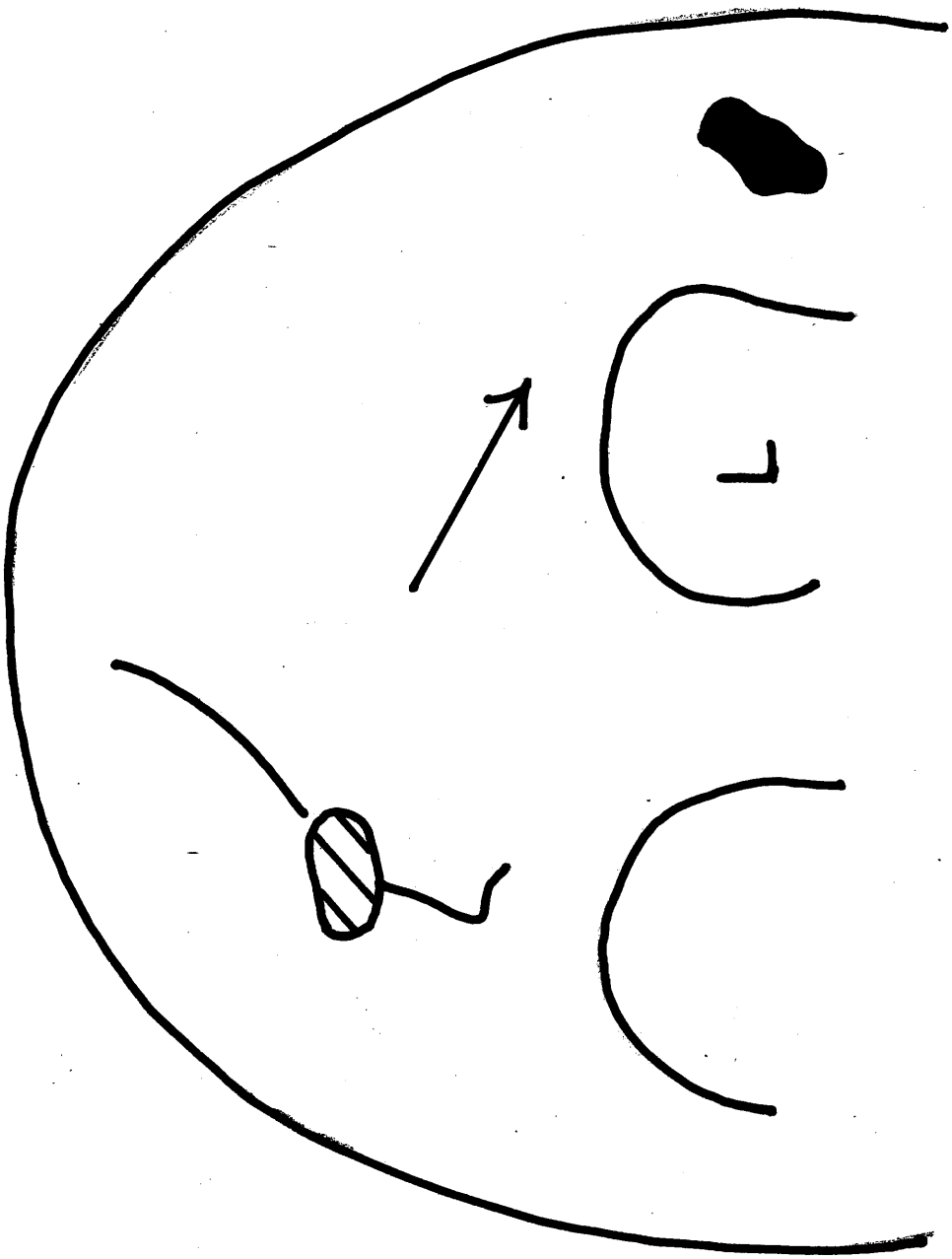
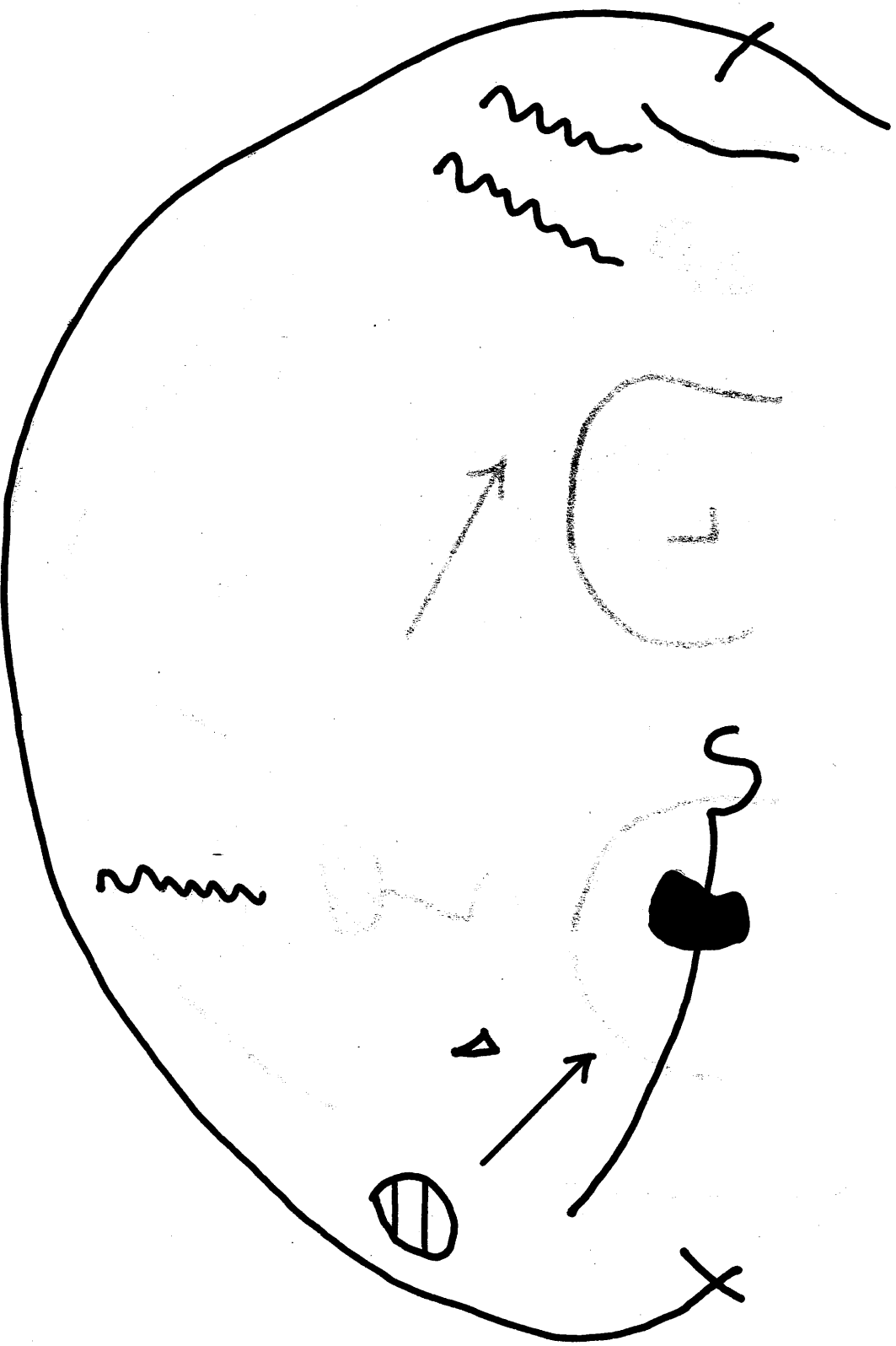


Figure 58.



1	2	3	4	5	6	7	8
64	R.-L. frontal. Entry R. supra-orbital region, track passed thro' R. frontal lobe & a small hole was seen in falx. Missile removed on L. from inside temporal muscle & splintered bone was removed from region of exit wound & missile track debrided along inferior surface of frontal pole (Fig. 58). 7.9.53 - L. frontal scar excised.	9 hrs.	8+	Much cort. air L.fr. region sugg. scar tissue w. atrophic cortex (1953)	Main focus L.frontal region (1953)	+	Destruction of L. eye from haemorrhage (globe intact) Bilateral hyposmia.

These cases must now be considered in some detail. Case No. 43 is excluded from consideration on the grounds stated in Table IX. In the remaining 9 cases the vocabulary levels were at or above the median level (26.5) for the normal controls, and if this is taken as a standard then they were all of normal or slightly above normal pre-traumatic intelligence. Their performance on the problem-solving tests was therefore lower than would have been expected from the vocabulary levels reached. In certain cases the level between one problem-solving test and another showed considerable fluctuation.

It must be recognised that many factors may influence this test performance. They were all men from the 1945 series and were being tested 7 to 8 years after injury, having grown older and having had to cope in the interval with often severe mental and physical disability, including traumatic epilepsy. Yet with the exception of Case 2 all were fully cooperative in the testing and were given every opportunity to do as well as possible. Moreover, such factors as mental and physical disability were equally distributed throughout the series.

It was felt, therefore, that the evidence in these cases suggested that some degree of intellectual deterioration or at least of impaired functioning was present. When the wounds were analysed it was found that they were all severe.

One further point of interest seemed to emerge from these cases. In 7 of the 8 cases in which the Dominoes Test was carried out the wounds involved homologous cerebral areas, in 2 cases the frontal lobes and in 5 the parietal lobes. In the frontal lobe cases the patient did relatively better on the Dominoes as compared with the Matrices; the reverse was true of the parietal lobe cases.

The S.G. on the Matrices and Dominoes in each of these cases, with the hemisphere involved in the wound and the patient's handedness, is shown in Table XI.

TABLE XI. S.G. ON MATRICES & DOMINOES; HEMISPHERE INVOLVED IN THE WOUND, & PATIENT'S HANDEDNESS IN 7 CASES INVOLVING HOMOLOGOUS CEREBRAL AREAS AND WITH DOUBTFUL INTELLECTUAL IMPAIRMENT.

Case No.	S.G. Matr.	Level Domin.	Dominoes Level Higher or Lower	Handedness	Hemisphere
FRONTAL LOBES					
29	IV	III+	H.	L.	R.
64	IV	III+	H.	R.	R. & L.
PARIETAL LOBES					
11	III-	IV	L.	R.	L.
30	IV	IV	-	R.	L. & R.
36	III-	IV	L.	R.	L.
48	III+	IV	L.	R.	L.
51	III-	IV	L.	R.	L.

The data in Table XI certainly suggests that the parietal lobe cases found the Dominoes Test less easy to do than the frontal lobe cases, presumably due to the counting element involved in it. This would indicate that in these parietal lobe cases there was an element of

dyscalculia, and this bore a definite relation to handedness and cerebral dominance.

It should be recalled, however, that the Dominoes was strictly timed, being limited to 20 minutes, whereas there was no time limit imposed on the Matrices. On the other hand, it is difficult to see why the frontal lobe cases did not do equally badly on the Dominoes.

It was thought worth while to investigate this a little further to see how significant the data presented in Table XI might be. It was realised from the testing of the normal controls that in spite of the apparently similar grading of the two tests the subject might easily produce a different S.G. on the Matrices and Dominoes. It was therefore decided to see on which of the two tests the subjects tended to do better. It was felt that it would be unfair to take the author's results on the Dominoes Test for comparison because, as has been shown, the scores tended to rise on this test on re-testing. It was decided, therefore, to compare the S.G. obtained on the Matrices (when tested by the author) with the S.G. obtained at Army entry on the Dominoes. This would mean that a comparison was being made on the scores obtained when the subject had done each test for the first time.

In the 26 normal controls on which the Dominoes Test had been carried out the S.G. on the Dominoes was the same as that on the Matrices in 8 cases; in 12 it was higher; and in 6 it was lower. This indicates that the normal

Figure 59.

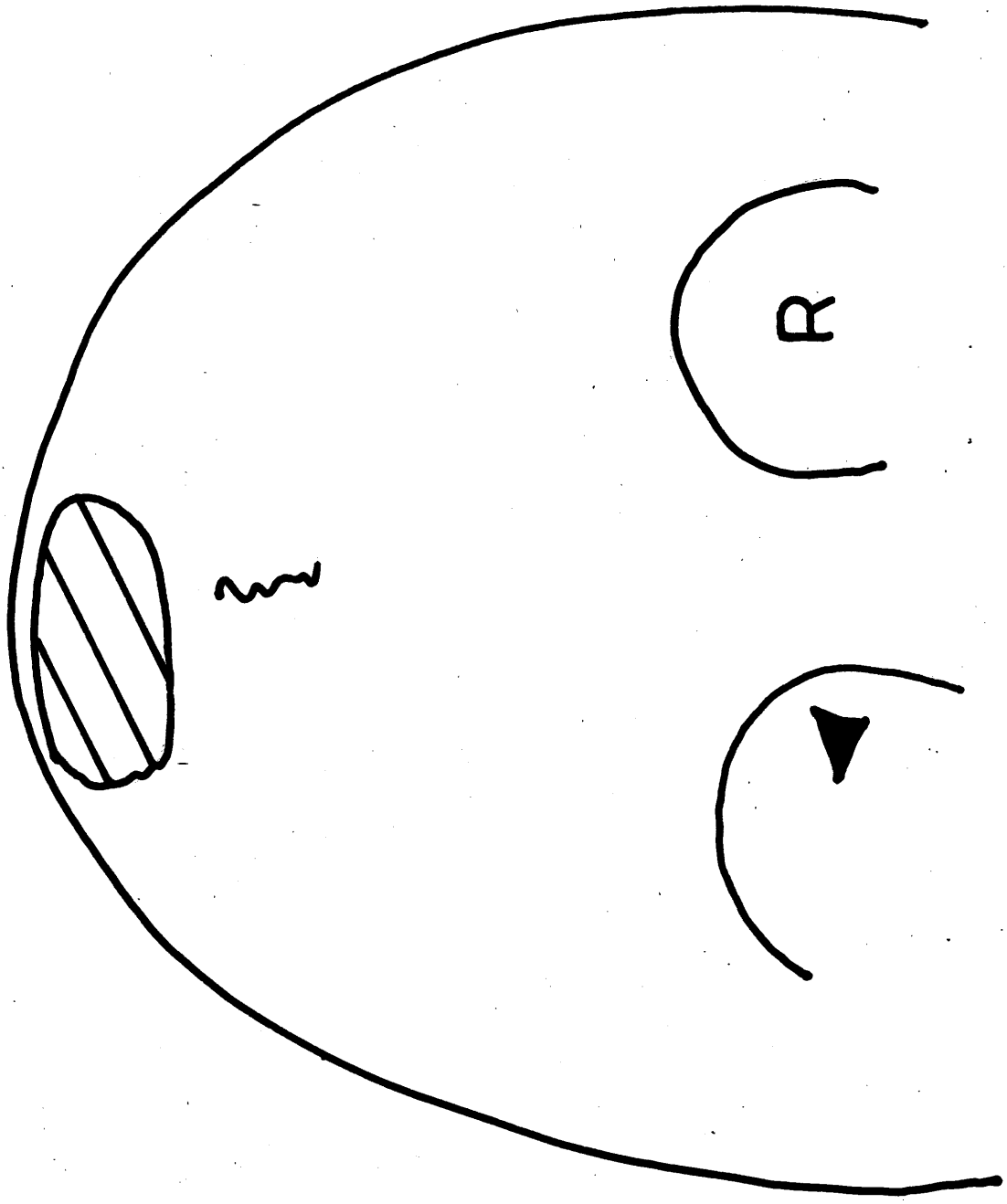
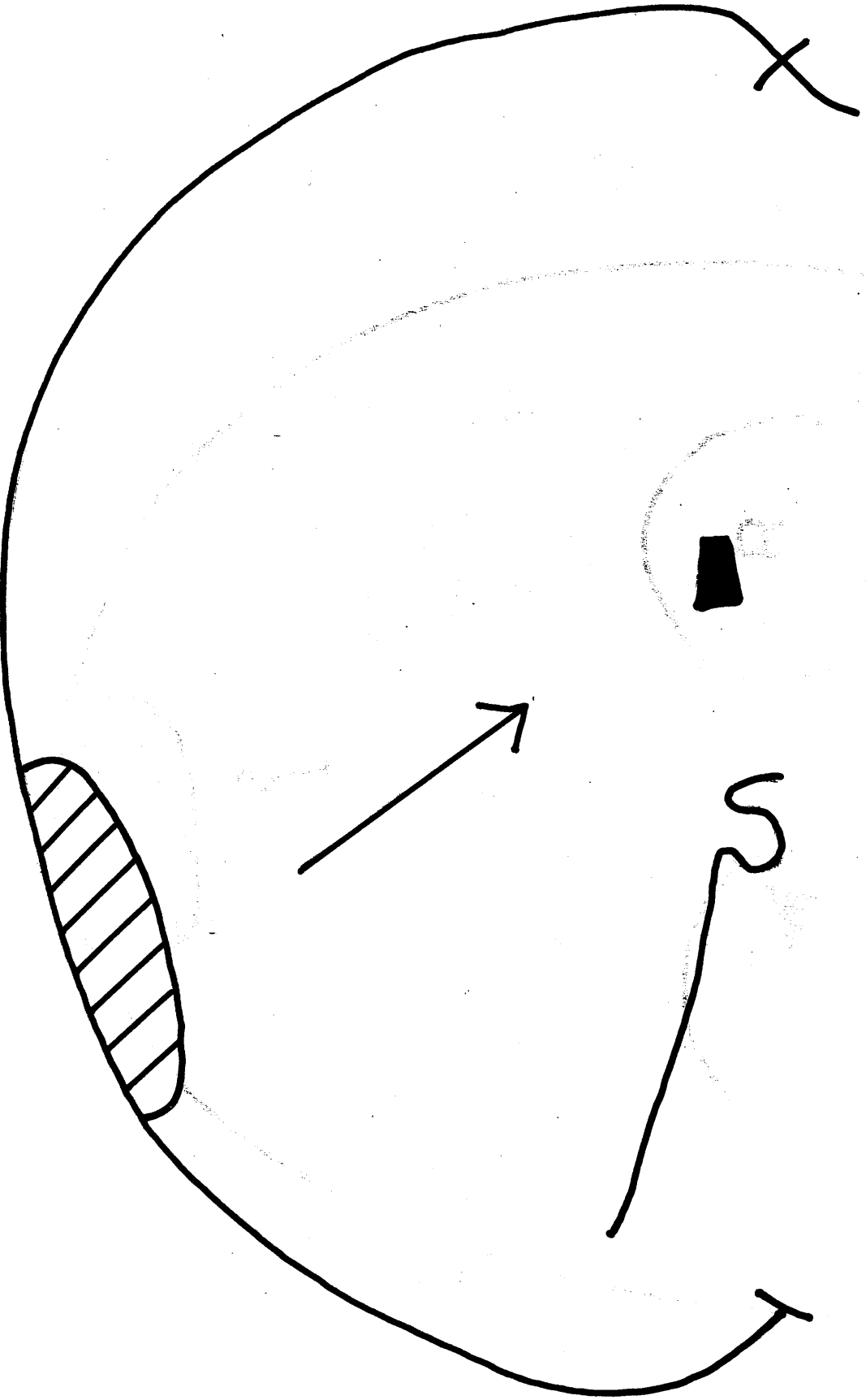


Figure 59.



subject does rather better on the Dominoes test than on the Matrices, in spite of the time limit, and this fact adds significance to the data presented in Table XI.

Group IV - Cases with Dysphasia.

There are 10 cases in which clinical evidence of dysphasia was present at the time of mental testing (Nos. 20, 21, 24, 25, 26, 27, 32, 33, 49 and 62). When the results were analysed it was found that in only 2 cases (Nos. 32 and 49) did the vocabulary score on the H.R.V. show the same sort of level as the scores on the problem-solving tests; in the other 8 cases it was significantly lower.

The 10 cases will each be described in a short history and a skull tracing (Figs. 59, 61, 63, 65, 67, 69, 71, 73, 75, and 77), and mental testing chart (Figs. 60, 62, 64, 66, 68, 70, 72, 74, 76 and 78) will be given in each instance.

The cases will be described in two groups, depending upon whether the vocabulary score was consistent with the scores on the problem-solving tests or not.

(a) Cases with vocabulary score consistent with scores on the problem-solving tests.

There were two cases in this group.

Case 32 (M.R.C. No. 805).

This 25-year-old captain was wounded in France on 18th March, 1945. A moderate-sized M.F.B. entered the left parasagittal region near the vertex and passed downwards, slightly backwards and laterally, to come to rest in the region of the left thalamus about 2.5 cm. behind the posterior clinoid process, having passed through the left lateral ventricleand left internal capsule.(Fig. 59). Bone fragments were indriven into the posterior frontal region

Figure 61.

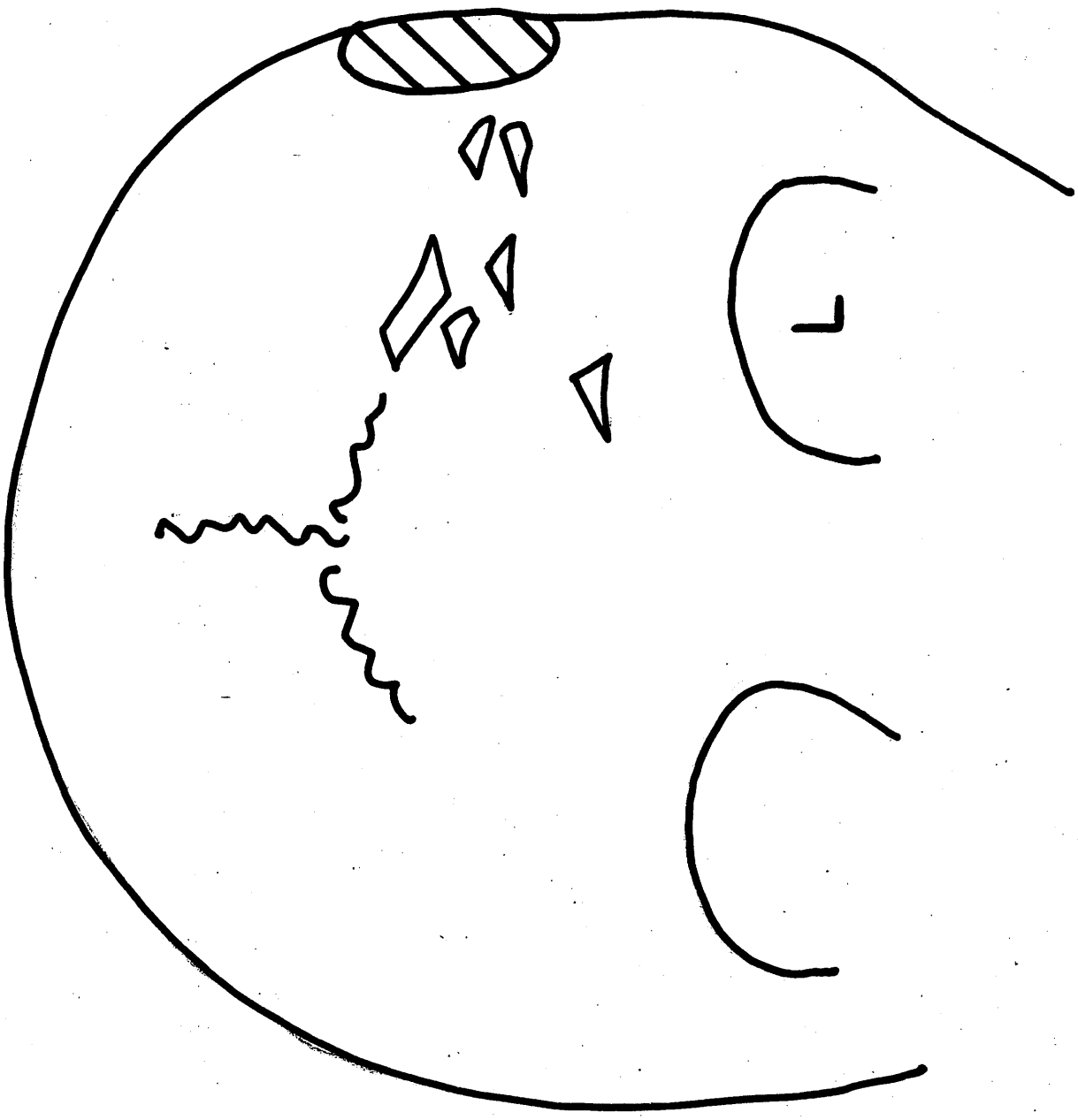
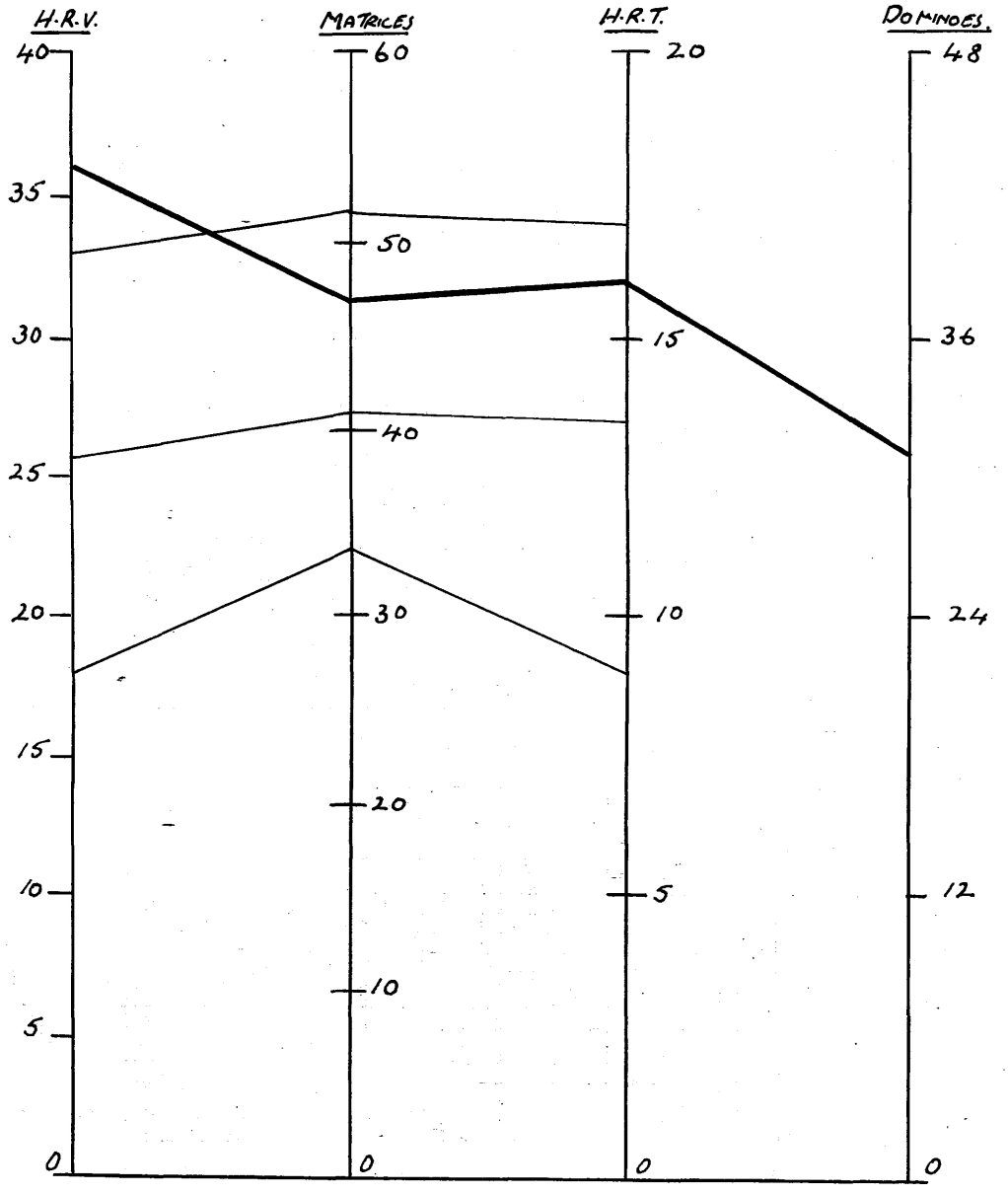


Figure 61.

Figure 60.


H.R.V.
MATRICES
H.R.T.
DOMINOES.
40
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0
20
15
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0
48
36
24
12
0

near the midline to a depth of 4 cm. At operation (Lt. Logue) it was seen that the missile had gone between the medial surface of the left hemisphere and the falx. Bone fragments and a small amount of necrotic brain were removed.

On admission to the Military Hospital for Head Injuries on 25th March he was mute but responded to direct questioning with a nod of his head. He appeared to understand almost anything that was said to him. There was a complete right hemiplegia, a gross right lower facial weakness, and a complete right hemianaesthesia, excluding the face. The R.A. was momentary and the P.T.A. a few minutes.

By 19th May, 1945, the dysphasia was recovering and was regarded as mainly expressive. He named 20 objects without hesitation, and read aloud as well and as rapidly as his difficulty with speech would allow. He wrote in block letters with his left hand, and comprehension was intact.

Subsequently he developed obesity and a tendency to sweat down the paralysed side suggestive of hypothalamic involvement. The right hand became slightly athetotic. Seven years later traumatic epilepsy had not developed.

He was examined by the author 7½ years after injury on 10th January, 1953, when mental testing was carried out (Fig. 60). His approach to testing was good. His scores were: H.R.V. 36; Matrices 47; H.R.T. 16; and Dominoes 31. No pre-injury scores could be obtained in his case. He left a grammar school at 16, after taking the matriculation examination, and entered the insurance business as a clerk. He was right-handed.

Case 49 (M.R.C. No. 889).

This 25-year-old sergeant was wounded in France on 17th January, 1945. There was a laceration 7.5 x 2 cm. in the left fronto-parietal region. The Sylvian vessels ran across the infero-posterior corner of the wound, and many had been severed. The track passed downwards and medially for about 7 cm. and contained 6 large bone chips (Fig. 61). Its medial wall was friable, and when investigated a broad, shallow layer of necrosed brain fell away, exposing the left frontal horn, which had blood clots filling it.

The R.A. could not be estimated; the P.T.A. was probably 2 days. He was aphasic, lacking in comprehension, and had a right hemiplegia including the face. There was cortical sensory loss on the right side affecting the arm more than the face and leg.

Figure 63.

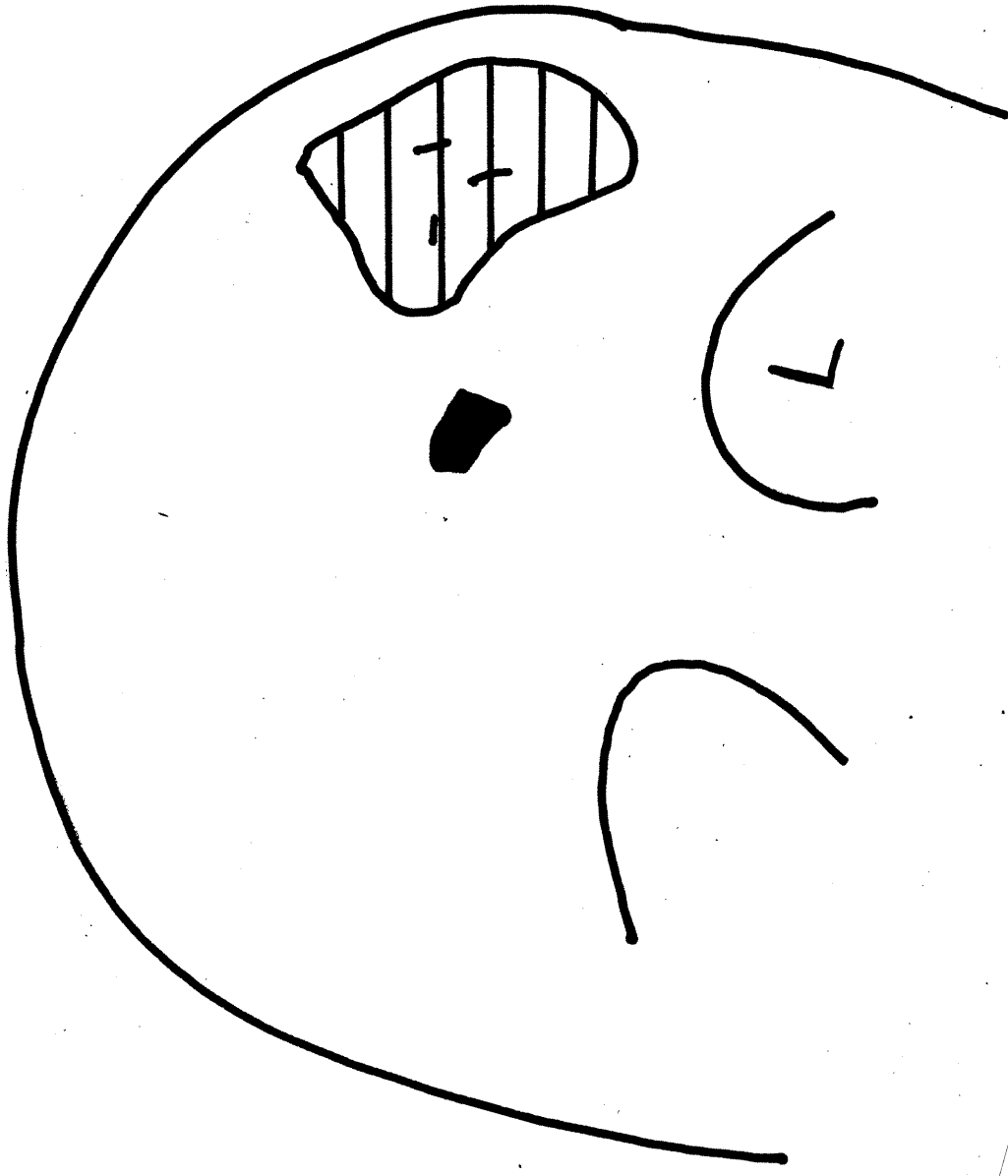


Figure 63.

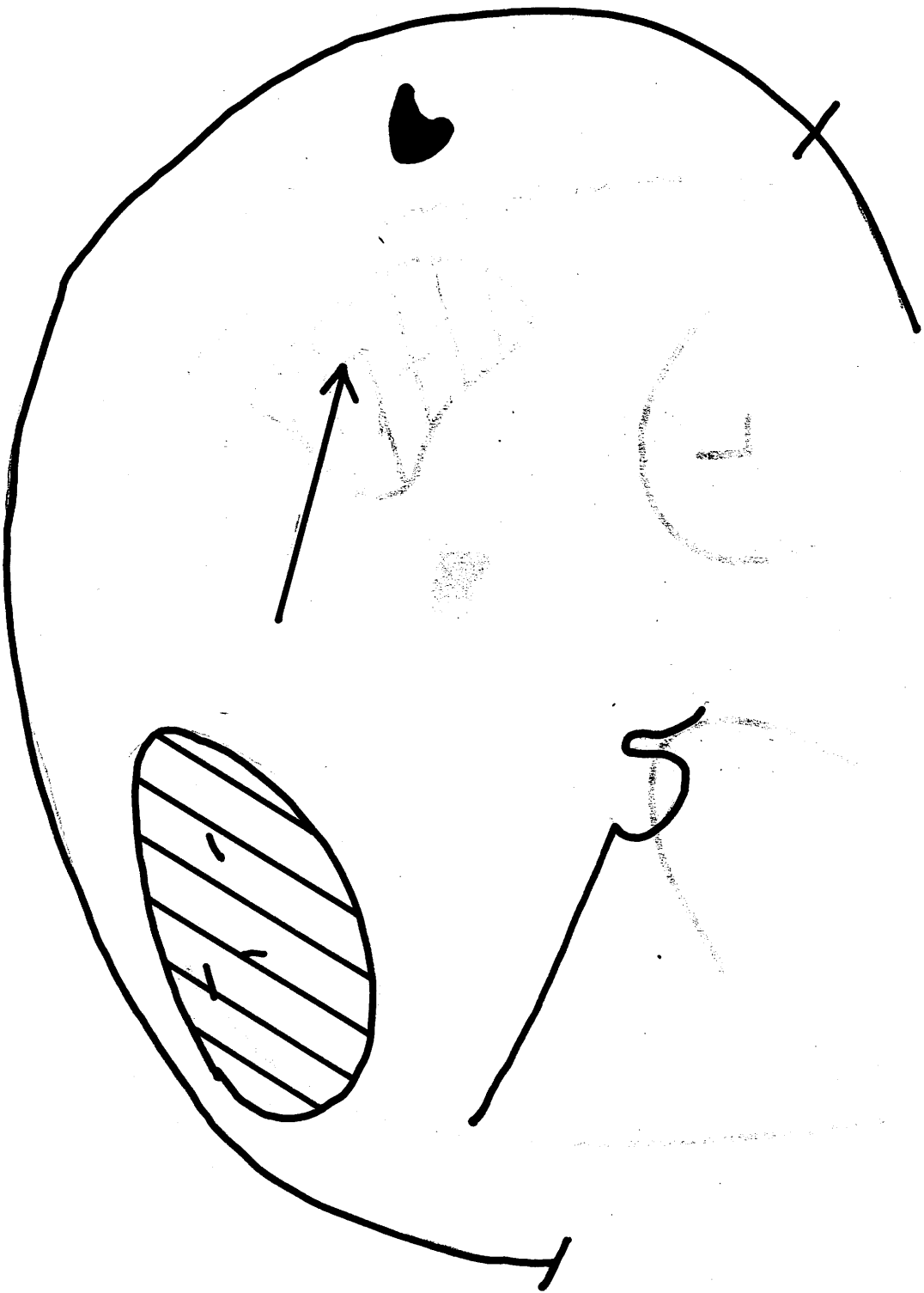
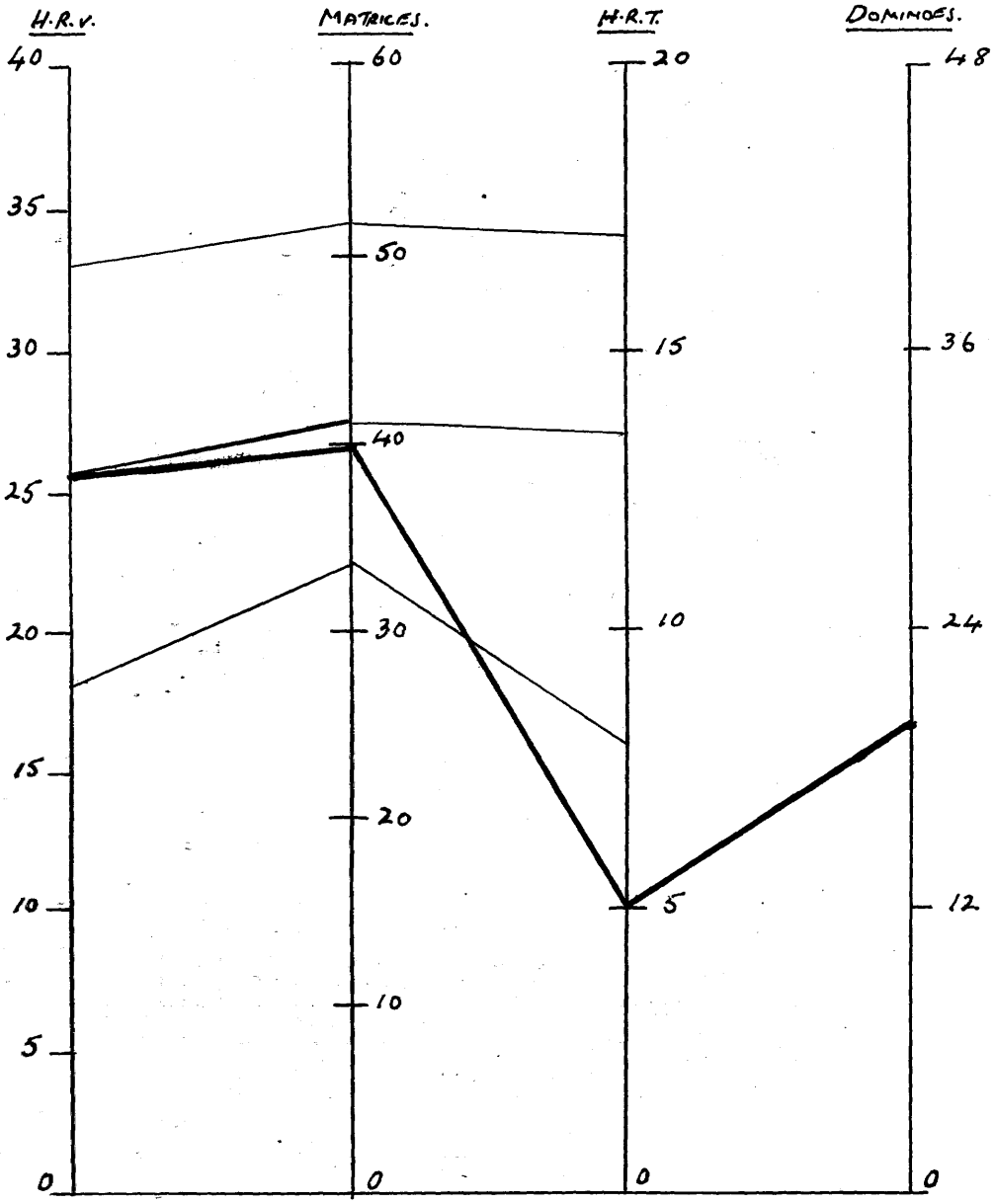


Figure 62.


H.R.V.
MATRICES.
H.R.T.
DOMINOES.
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Attacks of traumatic epilepsy began in November, 1945. Improvement in his speech had been noted, although he still had a severe degree of dysphasia; it was noted to be more expressive than receptive.

He was examined by the author 8½ years after injury on 9th July, 1953, when mental testing was carried out (Fig. 62). His scores were: H.R.V. 25; Matrices 40; H.R.T. 5; and Dominoes 20. No pre-injury scores could be obtained in his case. He had been tested by W.R.Reynell on 19th April, 1945, with the Matrices, when he also produced a score of 40. He had been a regular soldier for 11 years before his injury. He was right-handed.

(b) Cases with low vocabulary scores.

There were 8 cases in this group.

Case 20 (M.R.C. No. 977).

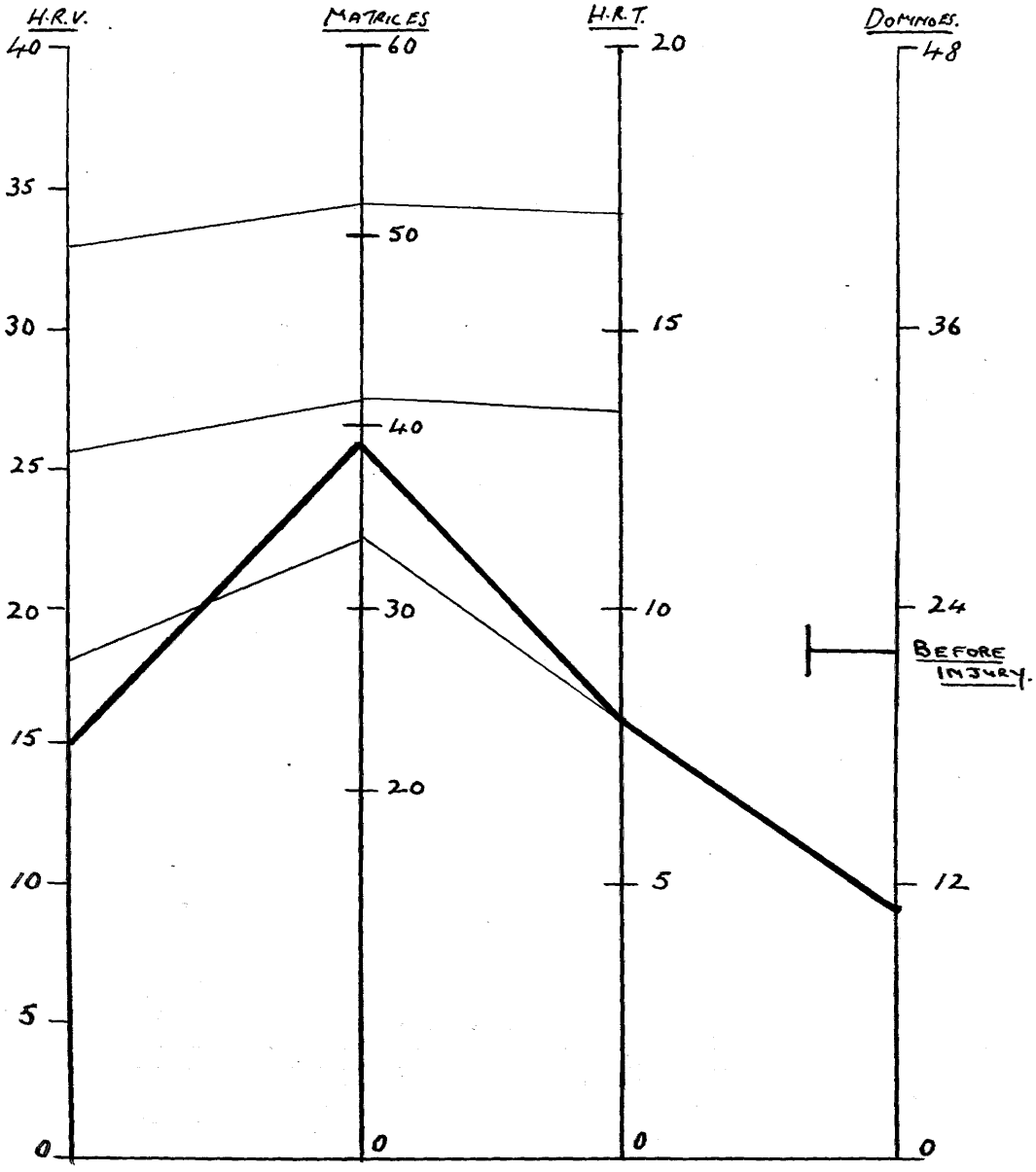
This 19-year-old corporal was wounded in Korea on 5th May, 1952. A shell fragment entered the left frontal region and passed directly backwards to come to rest just beneath the inner table of the skull in the posterior parietal region of the same side (Fig. 63).

On admission to an American neurosurgical unit 18 hours after injury he was semi-conscious, but responded to painful stimuli. At operation (Lt. J.C.Barnett) necrotic brain, sub-cortical clot and bone fragments were removed, as well as a small amount of subdural haematoma. The posterior end of the track could not be reached with the finger.

Five days after operation he was up and about. He had a spastic right hemiplegia, including the face, and marked aphasia.

On admission to the Military Hospital for Head Injuries on 13th June, 1952, he could only say "Yes" and "No", but was very lively and alert. There was a moderate hemiparesis, most marked in the arm, and slight cortical sensory loss in the right hand. An E.E.G. on 27th June showed irregular slow-wave activity over the whole of the left hemisphere, with a suggestion of a spike focus in the left frontal area. An A.E.G. on 30th June showed a generalised dilatation of the whole lateral ventricle on the left side. By 23rd August his speech had improved greatly and was now telegraphic, with frequent pauses for words and interjections of "Well" and "Yes". The visual fields were full to perimetry. He had his first attack of traumatic epilepsy on 2nd October.

Figure 64.


H.R.V.
MATRICES
H.R.T.
DOMINOES.
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BEFORE INJURY.

He was examined by the author 2 months after injury, on 9th July, 1952, when mental testing was carried out (Fig. 64). His scores were: H.R.V. 15; Matrices 39; H.R.T 8; and Dominoes 11. He showed good concentration. His performance on the Matrices was rather erratic, but he corrected his score to 45. He found great difficulty in doing the Dominoes and had to be helped with match-sticks to give the right numbers. He was able to count correctly a sum of money put on the table, add up a simple sum, and multiply 371 by 15; when, however, he was asked to subtract 3402 from 4718 he wrote down 9 as the answer to subtracting 2 from 8, and then expostulated, "I can't do it".

The Dominoes Test was repeated on 15th August, and on this occasion he produced a score of 7. All the tests were repeated on 28th August, and his scores were then: H.R.V 15; Matrices 44; H.R.T. 5; Dominoes 6.

He was seen again over a year later, on 14th October, 1953. On the H.R.V. he produced a score of 18 and on the Matrices 47. He would not cooperate on the Dominoes at all, and after trying for 20 minutes and producing no score, he said he could not do it. The H.R.T. was not done.

On Army entry on 7th October, 1950, his score on the Dominoes was 22 (S.G. IV). Taking his best score on this test when tested by the author (11) this meant that his Dominoes score had fallen by 11 points since wounding. There was no doubt that the dyscalculia resulting from his injury was seriously interfering with his performance on this test.

When tested for the first time on the Matrices his score was 39, which gave him an S.G. of III-. His overall S.G. on Army entry had also been III-. His performance on a verbal test on Army entry was also III-. His vocabulary score (15) when first tested on the H.R.V. was lower than would have been expected by his score on the Matrices.

In this case, therefore, there was evidence that the patient was functioning at his normal intellectual level on the Matrices, but that a loss in the understanding of words and a defect in calculation were interfering with his performance on the other problem-solving tests.

He left school at 14. He was regarded on Army entry as below average in intelligence and general education. Before entering the Service he was employed as a tailor's cutter. He was right-handed.

Figure 67.

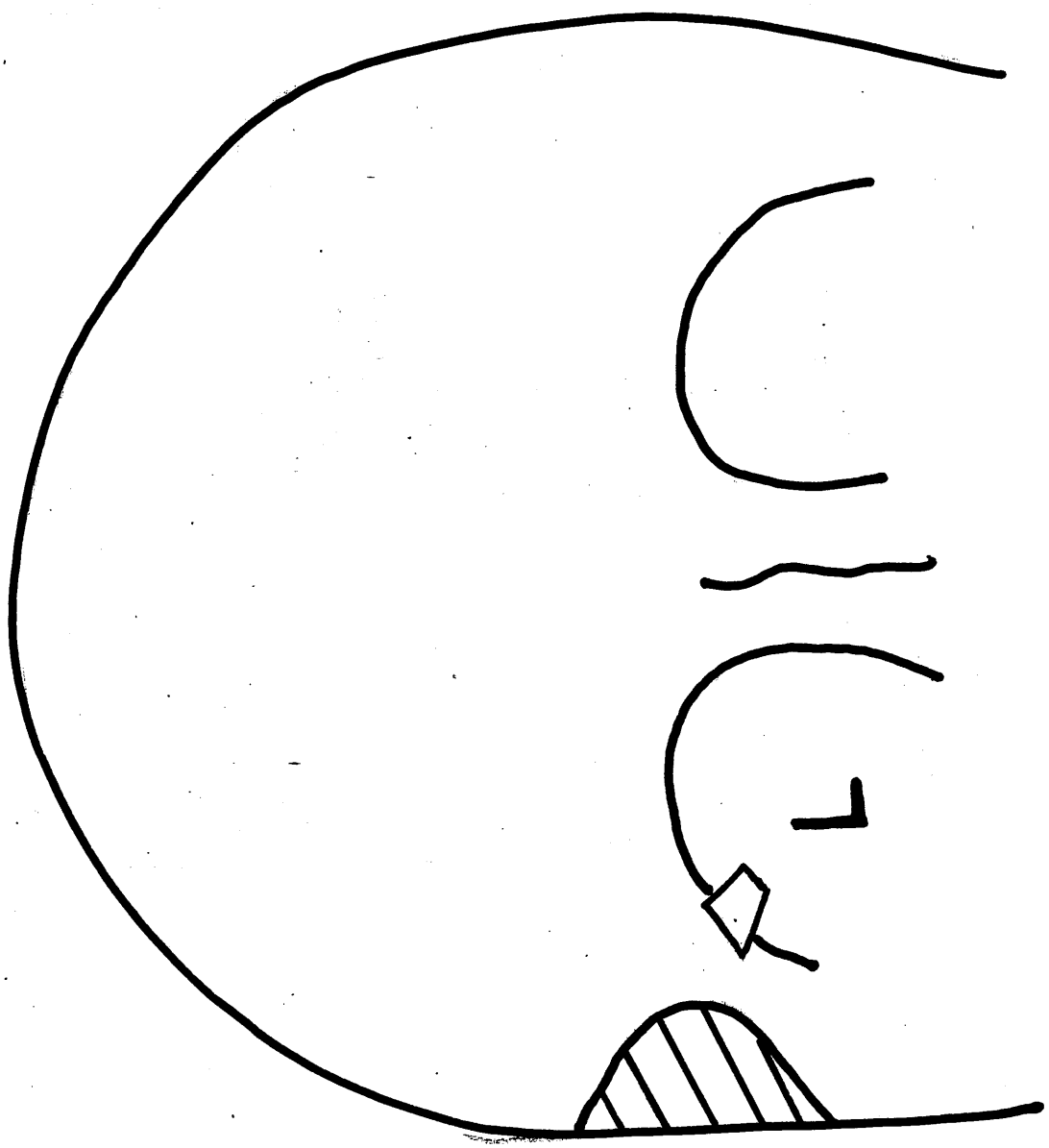

Figure 67.

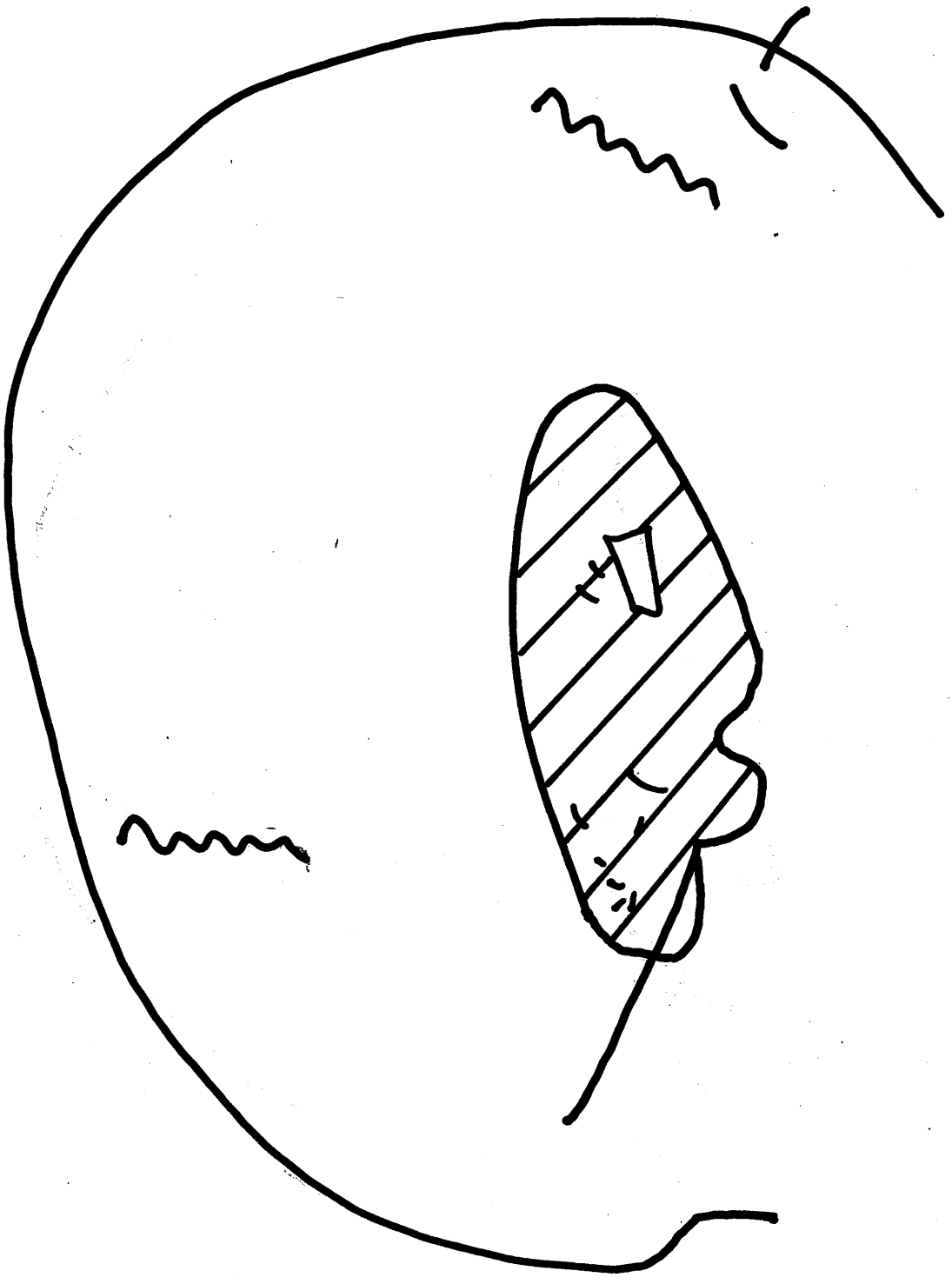

Figure 66.

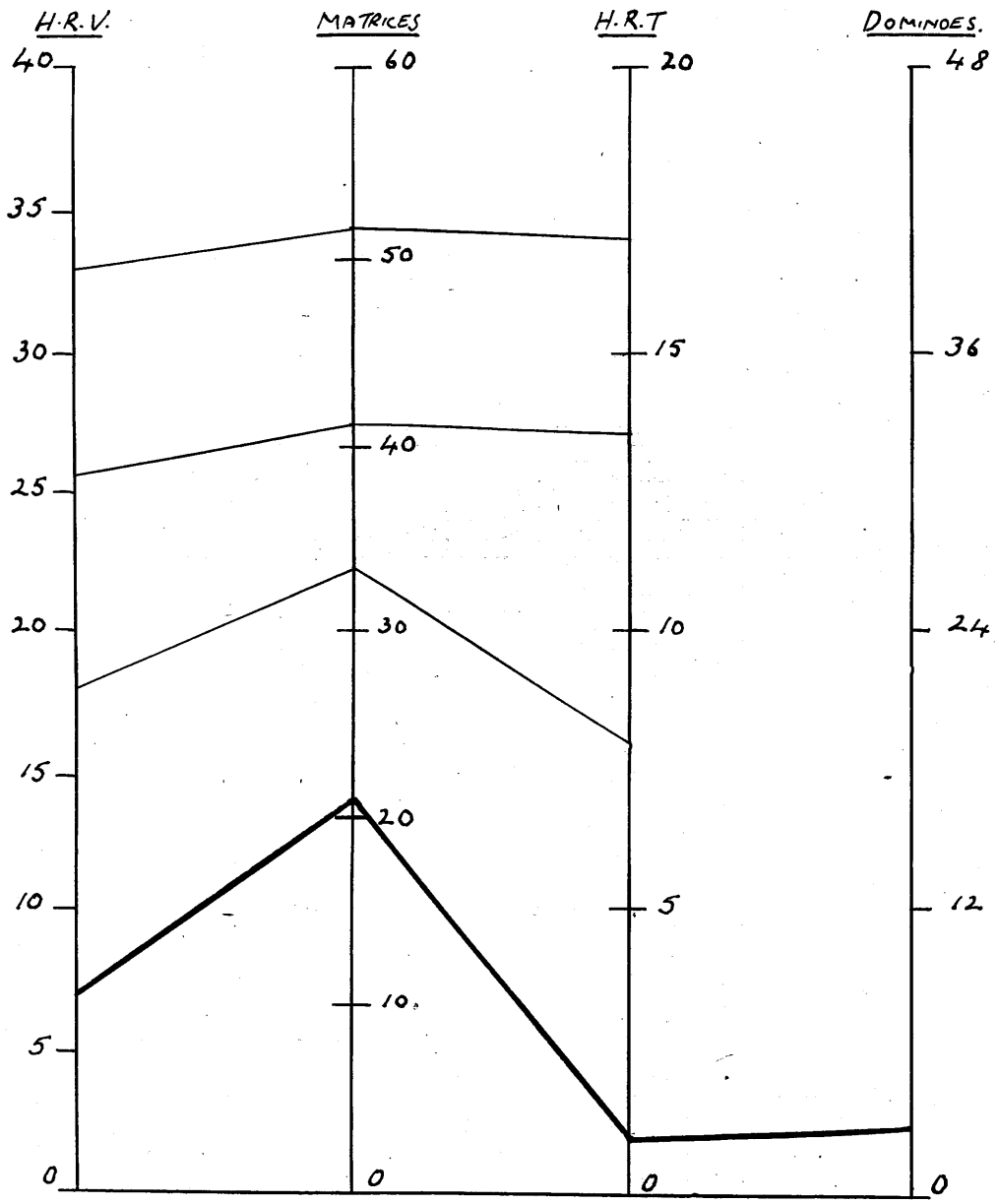
H.R.V.
MATRICES
H.R.T
DOMINOES.
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Figure 65.

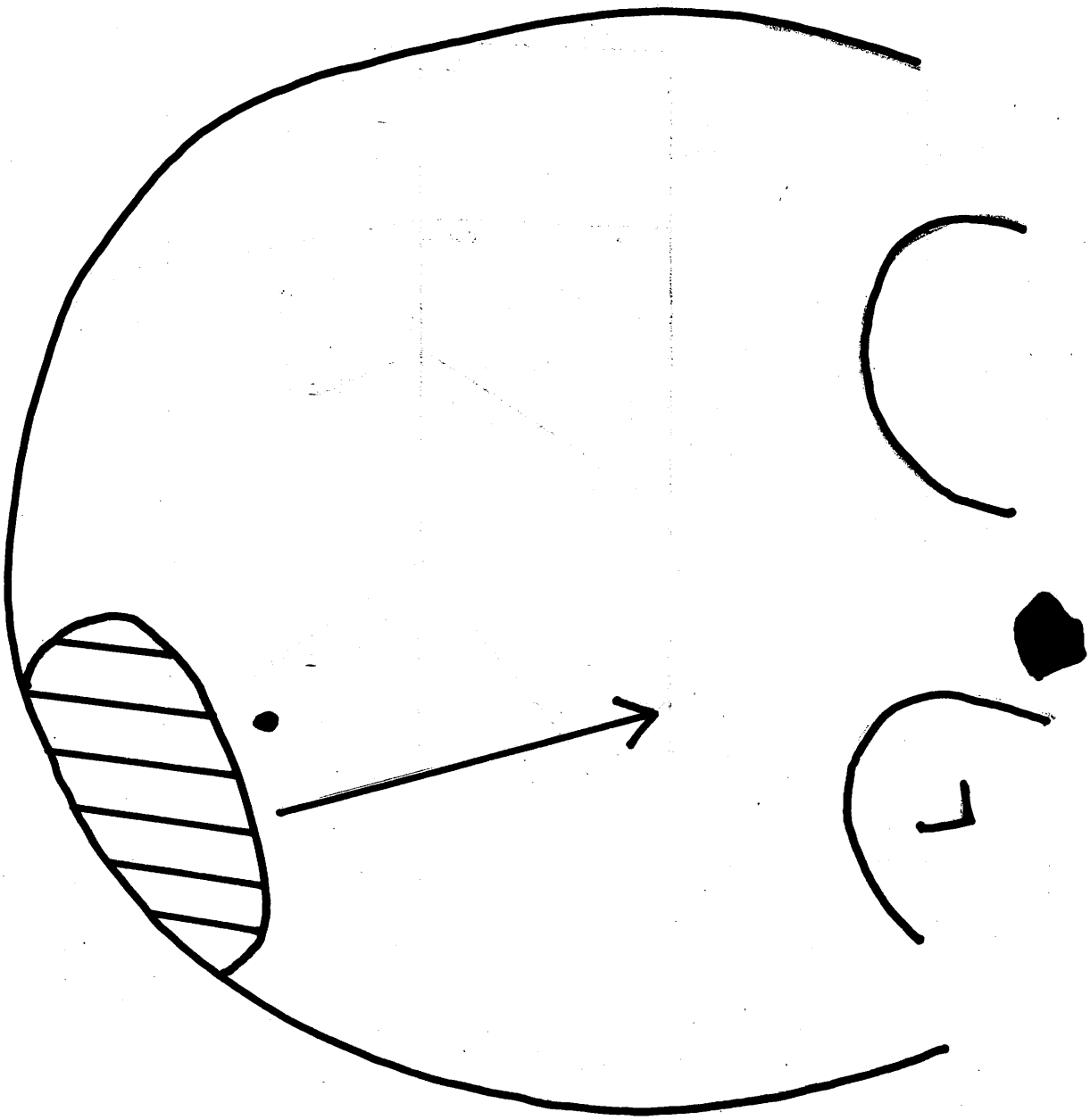


Figure 65.

Case 21 (M.R.C. No. 706).

This 33-year-old private was wounded in France on 19th August, 1944. A moderate-sized metallic fragment entered the left parietal region near the vertex, had passed downward in an antero-medial direction, through the left supra-orbital plate to come to rest in the nasal cavity (Fig. 65). At operation the next day the track, which was 9 cm. long, was cleared of lacerated brain and bone chips.

On admission to the Military Hospital for Head Injuries on 24th August he only understood a few simple commands and no written ones. The only word he could say was "Yes". He was incontinent. There was a right spastic hemiparesis and severe cortical sensory loss in the right arm and leg. A further operation was performed on 6th September, 1944, when brain which had herniated into the frontal sinus was removed and a fascial repair of the dura carried out. The R.A. was several hours; the P.T.A. 5 days. Attacks of traumatic epilepsy began in December, 1944. A further X-ray showed a minute metal fragment and a bone chip still present.

He was examined by the author 8 years after injury, on 11th July, 1952, when mental testing was carried out (Fig. 66). All testing was extremely difficult, owing to the obvious intellectual deterioration. He was still severely dysphasic. His scores were : H.R.V. 7; Matrices 21; H.R.T. 1; and Dominoes 3. No pre-injury scores could be obtained in this man's case. It is assumed that these scores show loss in all fields - verbal as well as problem-solving. Although this man was probably never very bright, the results of testing and his general mental state indicate a considerable degree of intellectual loss.

He left school at 14, worked on a farm for 8 years, and then in a steel mill. He was right-handed.

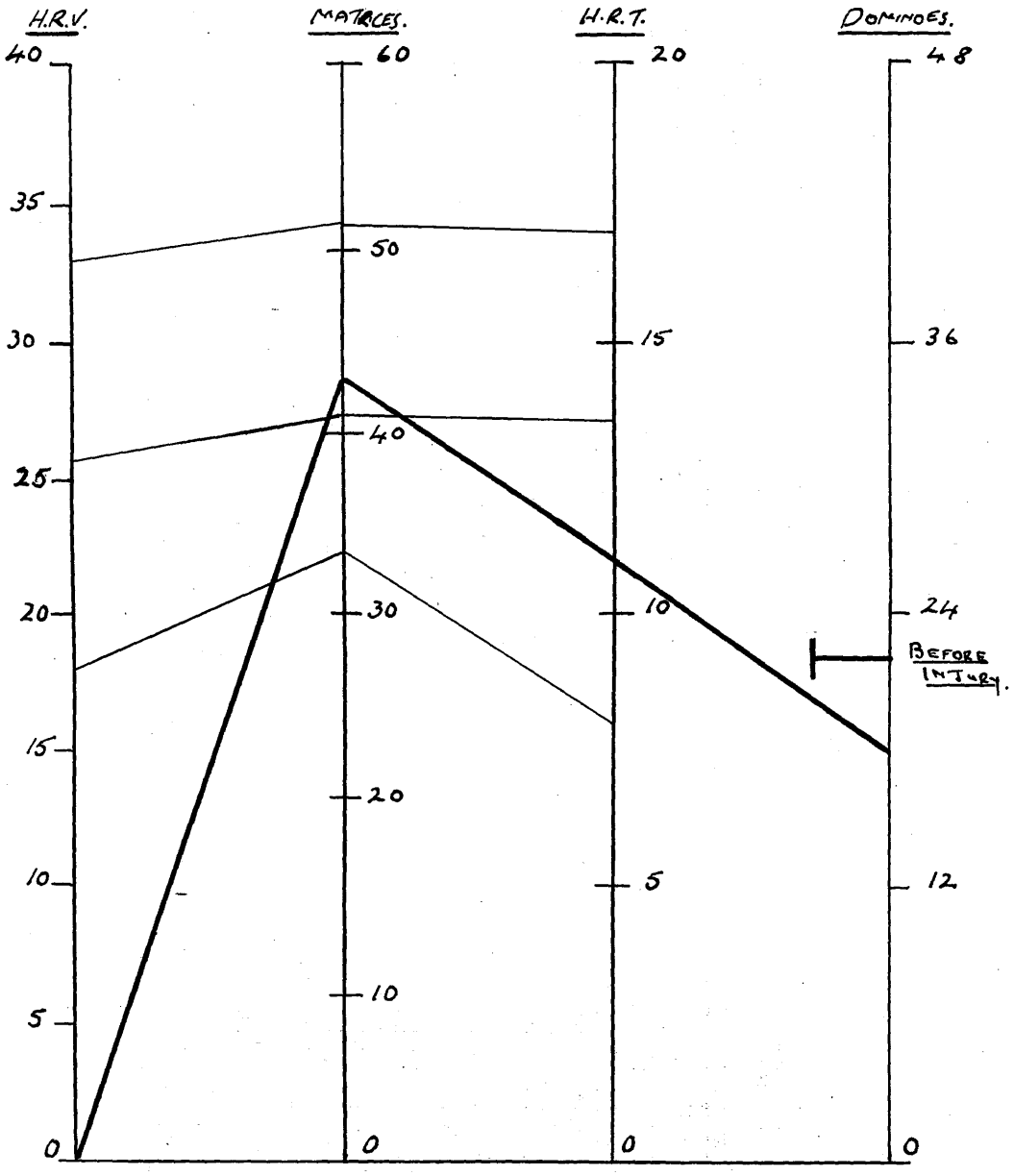
Case 24 (M.R.C. No. 976).

This 18-year-old private was accidentally wounded in Trieste on 23rd July, 1952. The wound in the left temporo-parietal region showed loose bone fragments and visible brain. The left ear drum was perforated. At operation 3 hours after injury (Capt. D.C.Cooke) three large pieces of depressed bone were removed and many smaller ones. In the centre of this area was a dural defect 1.5 cm. in diameter, and through this brain was herniating. Debridement of all dead tissue was performed (Fig. 67).

On admission to the Military Hospital for Head Injuries on 30th July, 1952, he was alert but dysphasic. There was

Figure 69.

Figure 68.


H.R.V.
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BEFORE INJURY.

right facial weakness and weakness of the right arm. Cortical sensory loss of the right arm and astereognosis of the right hand were also noted. The R.A. could not be estimated; the P.T.A. was 4 days. He was dyslexic and dysgraphic, but there was no dyscalculia. He developed right-sided focal sensory attacks in March, 1953, 8 months after injury.

He was first seen by the author a month after injury, on 21st August, 1952, when mental testing was carried out (Fig. 68). He was unable to make any attempt at the H.R.V., but his scores on the other tests were: Matrices 43; and Dominoes 18. The H.R.T. was not done. Re-testing was carried out on 23rd January, 1953, when his scores were: H.R.V. 3, Matrices 46; H.R.T. 11; and Dominoes 27. The H.R.T. had to be read out to him example by example, but he read the H.R.V. himself.

On Army entry on 15th May, 1952, he produced a score of 22 on the Dominoes, which gave him an S.G. of IV. His first score on this test after injury was 18, a fall of 4 points, which also gave him an S.G. of IV. His overall S.G. on Army entry was IV. His performance on the verbal test, however, gave him an S.G. of V.

He left school at 15, was stated to be good average at arithmetic but poor at spelling. He was regarded as being of poor native intelligence and indifferent edcuation. He was a laundry vansman before entering the Army. He was left-handed and left-footed. Two sisters were also left-handed.

Case 25 (M.R.C. No. 6).

This 20-year-old marine was accidentally wounded by his own Sten gun on 17th June, 1944. There was a small wound of entry through the left ear and a large exit wound in the left parietal region (Fig. 69). He was dysphasic, with a complete right hemiplegia and right-sided sensory loss. He was operated on a few hours after injury (Major J.A.V.Nicoll), when herniating brain and loose fragments of bone were removed from the wound.

He was admitted to the Military Hospital for Head Injuries on 22nd June in coma; a second operation was performed (Brig. Cairns). There was a large dural tear 6 cm. in diameter in connection with the exit wound, and one about 4 cm. in diameter in connection with the entry wound, with a bridge of intact dura about 3 cm. wide in between. Pulped brain, clot, and bone chips had to be cleared from the wound. There was extensive ploughing up of the left temporal and parietal cortex, and the vessels of the Sylvian fissure.

Figure 71.

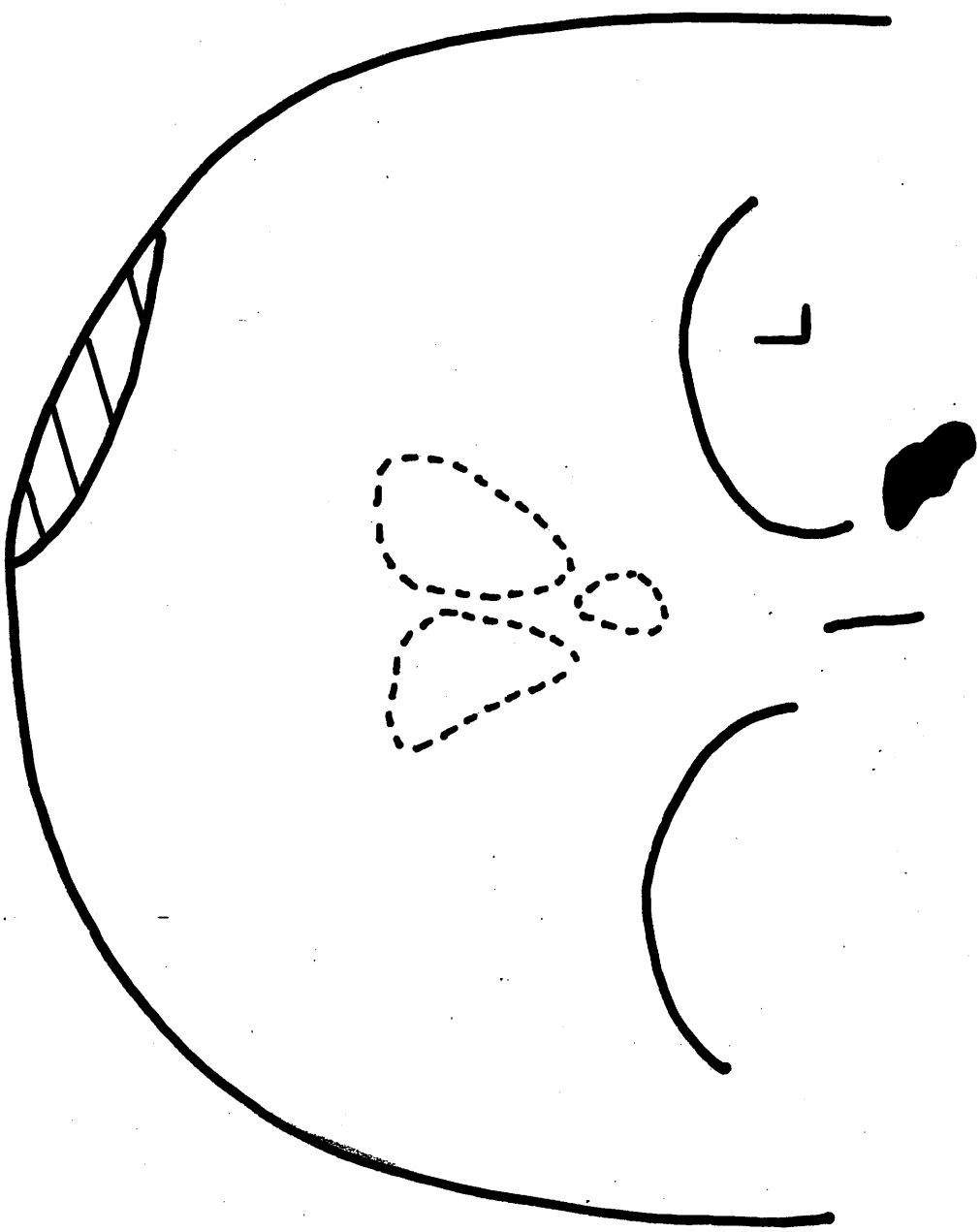


Figure 71.

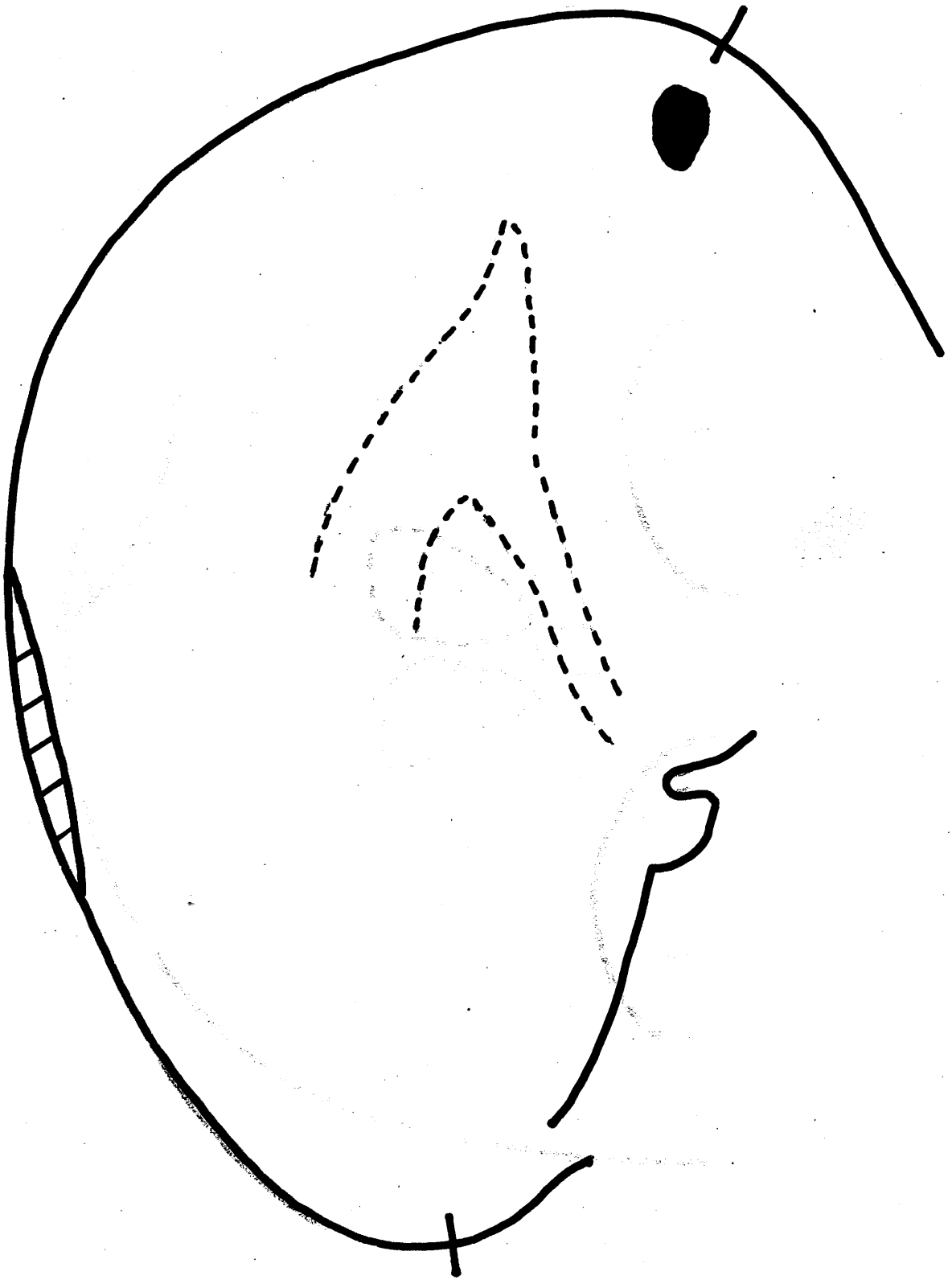
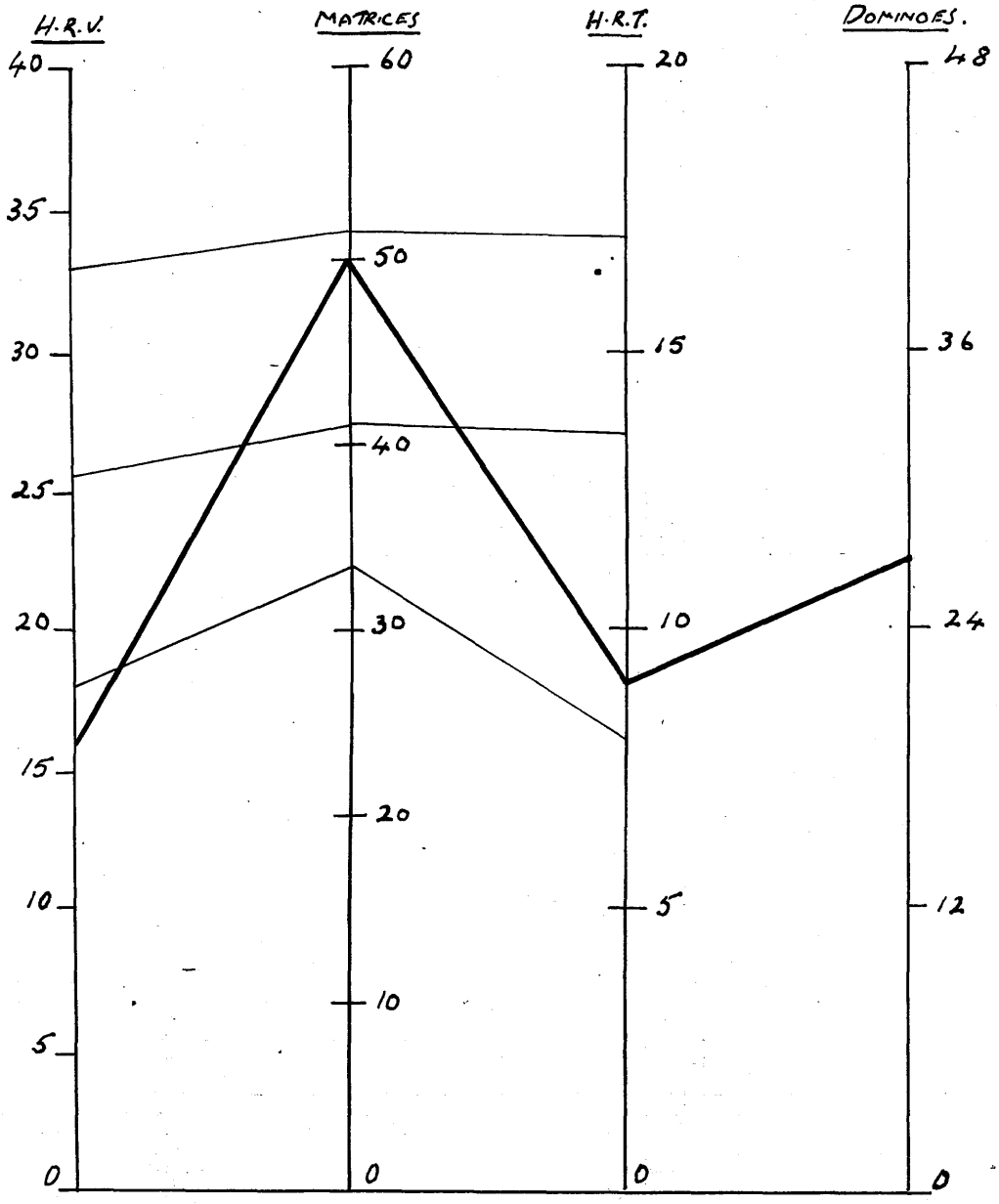


Figure 70.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By 28th June he was fully alert. P.T.A. was 1 week. There was complete motor aphasia, alexia, marked sensory dysphasia and dysgraphia. There was no dyspraxia. He was now responding to simple spoken commands. There was a right homonymous hemianopia to charting, most complete in the upper quadrants.

He was first seen by the author 8 years after injury, on 7th August, 1952, when mental testing was carried out (Fig. 70). His scores were: H.R.V. 16; Matrices 50; H.R.T. 9; and Dominoes 27. His score on the Matrices gave him an S.G. of II and on the Dominoes of III-. His performance on the H.R.T. was rather low, while his vocabulary level (16) was much lower than would have been expected by his performance on the Matrices and the Dominoes. No pre-injury scores were available in his case. His dysphasia was still marked, and his speech was telegrammatic - he missed out prepositions and conjunctions frequently - "It's the small words that are the worst - they just don't ring a bell". As can be seen from the vocabulary test, the verbal difficulty was certainly not confined to the small words.

He left school at 14, was a fair scholar, and had several labouring jobs before joining the marines. He was right-handed.

Case 26 (M.R.C. No. 981).

This 19-year-old private was accidentally wounded in Hong Kong on 24th April, 1951. A moderate-sized metallic fragment entered the left anterior parietal parasagittal region, passing downwards and backwards to come to rest in the left occipital region (Fig. 71). At operation the same day (Lt-Col. Spence) the wound was debrided and three small bone fragments were removed.

He was admitted to the Military Hospital for Head Injuries on 3rd May, 1951. On admission he was conscious but severely dysphasic. There was a right homonymous hemianopia, paresis of the right arm, and spastic paresis of both legs. There was a large fluctuant mass beneath the wound, and his condition had deteriorated. A second operation was performed on 4th May (Mr. Lewin). Masses of disintegrating brain and clot were released when the wound was re-opened. The wound track went backwards, downwards, and medially alongside the falx, and as it was opened up more brain tissue, clot, and several bone chips escaped. Firm brain was reached at a depth of 8 cm. The track lay above and medial to the ventricle. Post-operative improvement was rapid.

Figure 73.

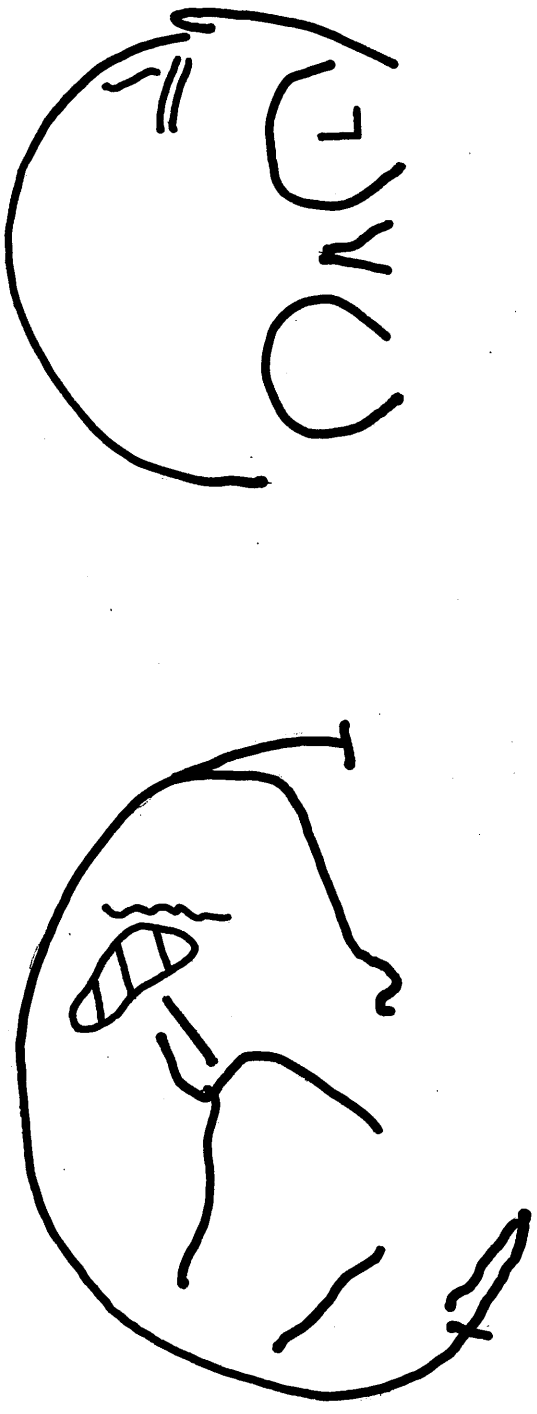
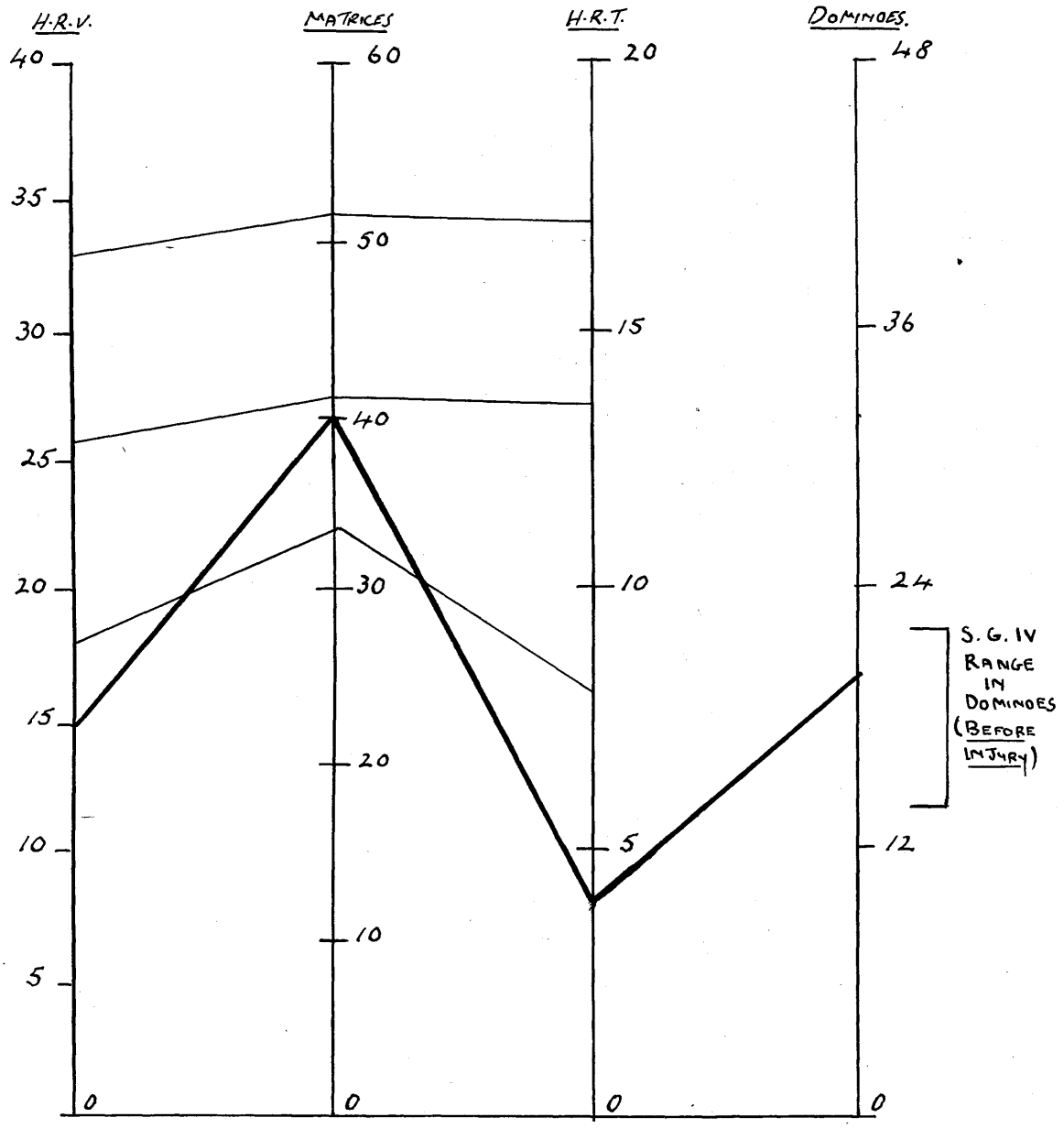


Figure 72.


H.R.V.
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S. G. IV RANGE IN DOMINOES (BEFORE INJURY)

By 26th July power was returning to the right arm; the left leg was strong, but the right still weak. The R.A. was a few minutes; the P.T.A. 3 weeks.

An A.E.G. on 11th July showed slight dilatation of the left lateral ventricle, with minimal traction towards the skull defect.

When readmitted in 1952 he reported two attacks of traumatic epilepsy. There was a right upper quadrantanopia and some right hemiparesis. There was no sensory defect.

He was first seen by the author 16 months after injury, on 13th August, 1952, when mental testing was carried out (Fig. 72). His scores were: H.R.V. 15; Matrices 40; H.R.T. 4; and Dominoes 20. The only information which could be obtained about his intellectual level before injury was that he had been graded as S.G. IV on Army entry on 4th August, 1949. Actual scores were not available. His score on the Matrices gives him an S.G. III- and on the Dominoes an S.G. IV. There would appear therefore to be no intellectual deterioration on problem-solving tests. His dysphasia was not marked clinically, but he had occasional difficulty in word-finding. His vocabulary score is lower than would be expected by his performance on the problem-solving tests. He was right-handed. He left school at 14, and was a labourer before enlistment.

Case 27 (M.R.C. No. 54).

This 20-year-old corporal was wounded in France on 28th June, 1944. He was operated on 70 hours after injury (Capt. Hartley); there was a left posterior frontal wound with an underlying bone defect 2.5 x 1 cm., but only one or two small bone fragments were seen (Fig. 73).

He was admitted to the Military Hospital for Head Injuries on 2nd July, when a further operation was performed (Brig. Cairns). There was an oval wound 10 x 5 cm. just below the parietal eminence and extending down in the temporal region. Much offensive brain tissue flowed from the wound, and the dural tear extended down to the mastoid. At the upper posterior part of the dural tear was an abscess which extended in for a depth of about 4 cm. When the wound was dressed 10 days later the interior of the ventricle was seen to be exposed.

The R.A. was a few seconds; P.T.A. 14 days. He had a right lower facial weakness and a right hemiparesis. Complete loss of cortical sensation over the right arm was noted.

Figure 75.

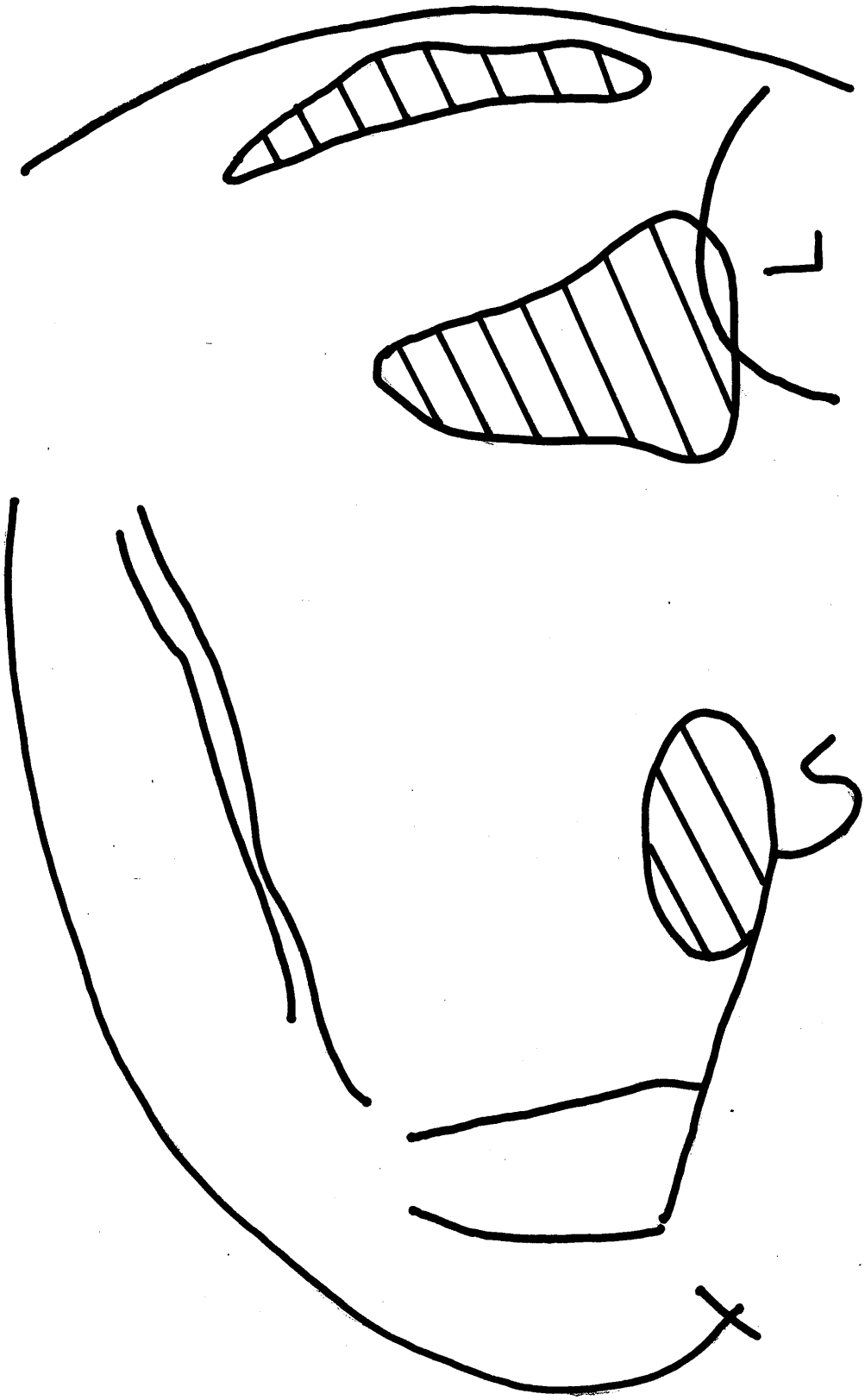
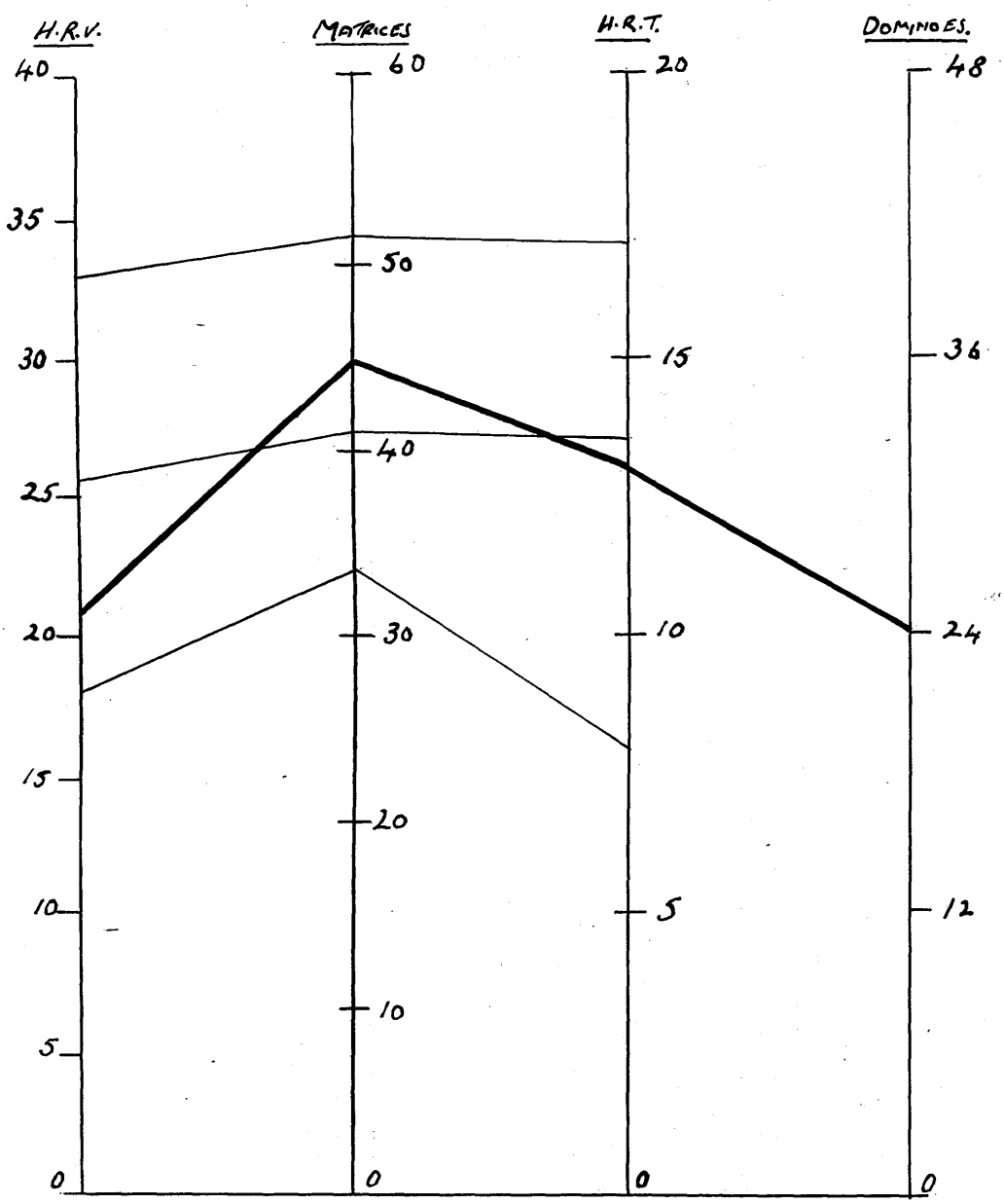


Figure 74.


H.R.V.
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His dysphasia, which was marked in the early stages of his injury, improved considerably within a few weeks, and seemed to be mainly expressive, although on specific testing on 30th August he called a tobacco pouch an ash-tray. Traumatic epilepsy began in September, 1944. An A.E.G. on 27th October, 1944, showed a general dilatation of the left lateral ventricle and of the anterior part of the right. There was also a gross focal dilatation of the body and trigone of the left lateral ventricle underlying the defect and of the the temporal horn. The anterior part of the system was drawn towards the defect, but the posterior part remained central.

When mental testing was carried out on 31st October he was noted to be dyslexic and dysgraphic, in addition to being dysphasic. There was no dyspraxia.

He was first seen by the author on 18th August, 1952, 8 years after injury, when mental testing was carried out (Fig. 74). His scores were: H.R.V. 21; Matrices 45; H.R.T. 13; and Dominoes 24. No pre-injury scores could be obtained in his case. His score on theMatrices gave him an S.G. of III+ and on the Dominoes III-. When tested on the 31st October, 1944, his score on the Matrices was 47 (S.G. III+). These scores suggest that he is functioning within his normal intellectual range on the problem-solving tests, but that his verbal ability is reduced.

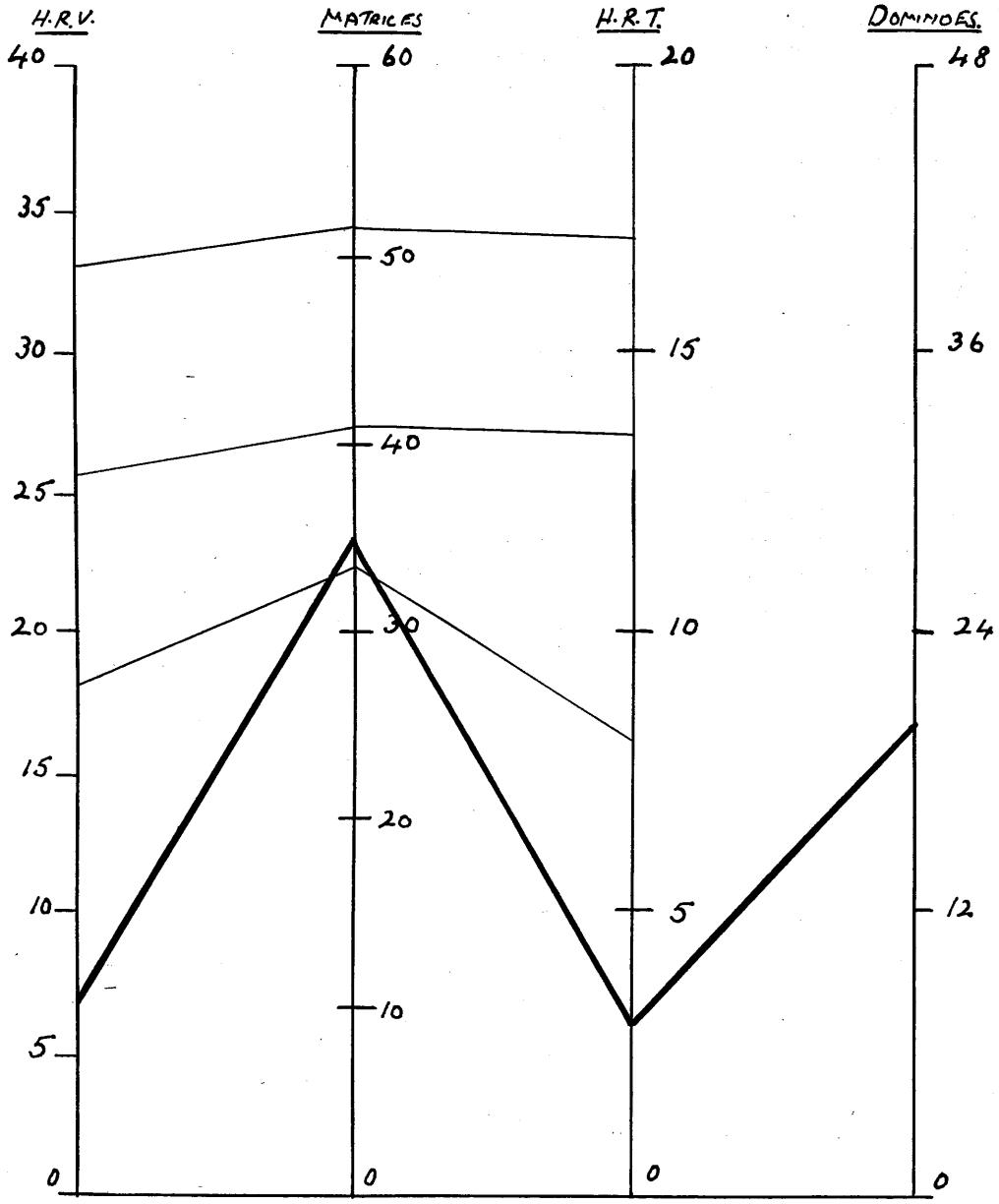
He left school at 14, was a good scholar, and was a shop-assistant before joining the Service. He was right-handed.)

Case 33 (M.R.C. No. 417).

This 19-year-old private was wounded in France on 20th July, 1944. He sustained a through-and-through wound, left frontal to left temporal, involving the left orbit and destroying the globe (Fig. 75). At operation (Major Small) 26 hours after injury there was gross comminution of the frontal and temporal bones, fragments of which had to be removed widely from the frontal region and down into the temporal fossa. The supra-orbital plate was severely comminuted and had to be removed. Lacerated brain of the frontal and temporal lobes had to be widely excised from the falx to the base of the temporal fossa.

On admission to the Military Hospital for Head Injuries on 27th July he was drowsy, confused, and incontinent of urine. There was a right hemiparesis, including the face, and bilateral anosmia. He was noted to perseverate in his speech, but there was no nominal dysphasia.

Figure 76.


H.R.V.
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As he recovered he showed considerable apathy and lack of initiative.

Mental testing (Major W.R.Reynell) was carried out on 31st October, 1944. He was regarded as a backward Irishman who had left school at 12 and worked as a gardener until he joined the Army. He was stated never to have learned to read or write, but showed interest when given non-verbal tests. His performance on tests of block design and digit symbol gave him an I.Q. of 80. He was regarded as having a congenital linguistic defect which rendered him backward in all school subjects and in reading and writing. His performance on the Matrices was only a little below average (unfortunately no scores are given).

He was admitted to Headington Hill Hall for review in February, 1953. Definite dysphasia was noted, and he misnamed 3 common objects out of 15. He read well. The left eye had been enucleated, and there was a right upper quadrantanopia. There was no marked motor or sensory deficit. An E.E.G. showed some slow waves in the left frontal region. There had been no fits since injury.

The dysphasia was confirmed by the visit of a social worker to his home, when his brother reported that he was "very short of words, could hardly speak at all after his injury, and now often can't find the word he wants or uses wrong words entirely". He agreed that he was not very bright at school.

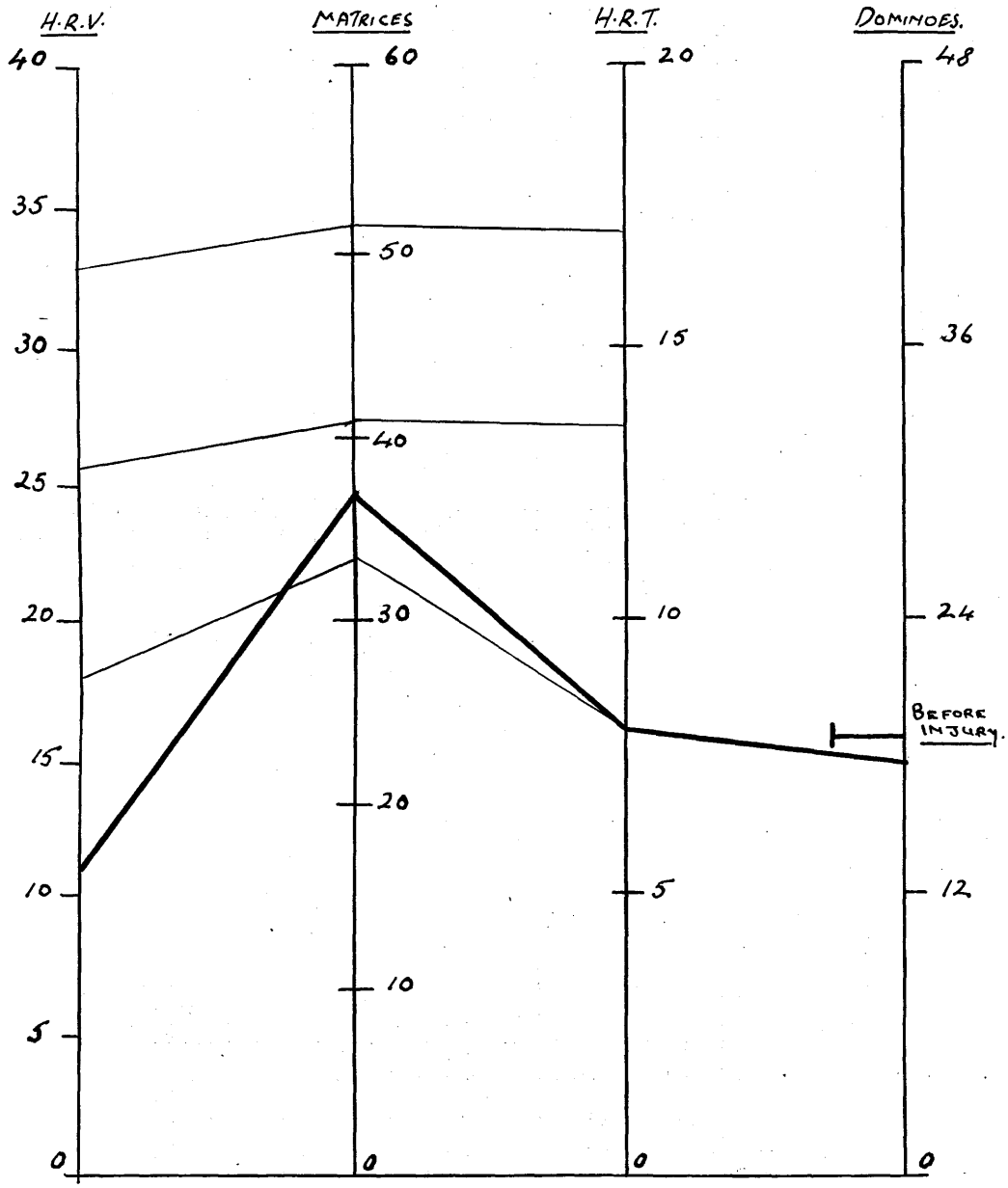
He was examined by the author on 25th February, 1953, when mental testing was carried out (Fig. 76). The patient confirmed his difficulty with speech since injury and was often stuck in understanding the meaning of a word in reading. His scores on the tests were: H.R.V. 7, Matrices 35; H.R.T. 3; Dominoes 20. The scores on the Matrices and Dominoes gave him an S.G. of IV, which probably, in view of his history, is his normal intellectual level.

In this case the evidence for a congenital linguistic defect is doubtful, and he appears to have had a real verbal difficulty since injury which is confirmed by his performance on the H.R.V. His performance on the H.R.T. is also low. He was right-handed.

Case 62 (M.R.C. No. 1001).

This 20-year-old fusilier was wounded in Korea on 25th November, 1952. On admission to an American neurosurgical unit the next day he was confused and irrational. Skull films showed an intracranial fragment on the left side which

Figure 78.


H.R.V.
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DOMINOES.
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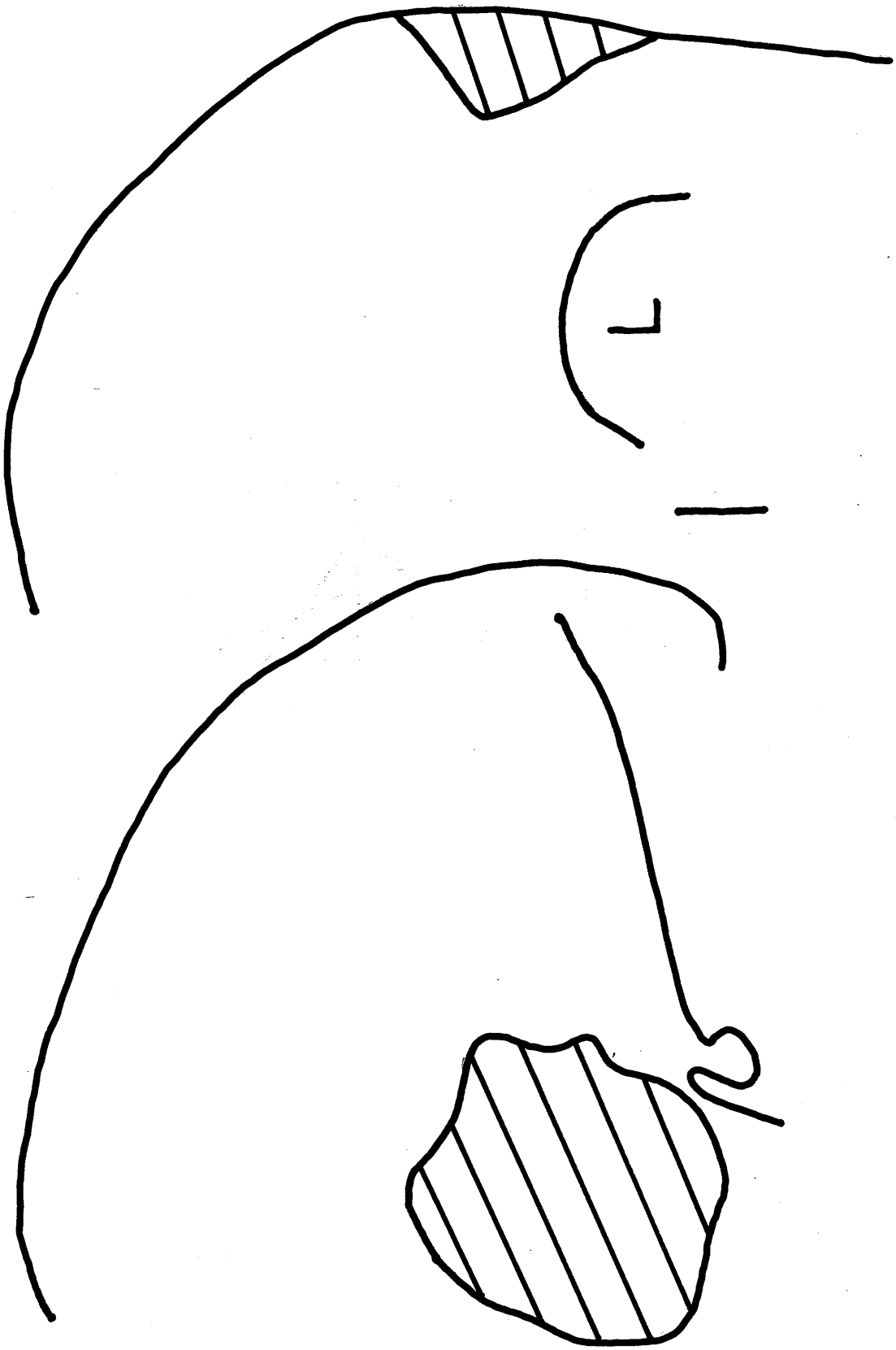
BEFORE INJURY.

Figure 77.



changed position in different X-rays; it was considered to have entered the ventricular system.

At operation on 26th November (Lt. J. Ninecurt) the temporal lobe was retracted medially and the site of entry was visualised in the middle fossa. Several bone fragments were removed, and the necrotic anterior pole of the temporal lobe was debrided. The index finger was introduced into the ventricle and the fragments removed.

Post-operatively the patient did well, but had a marked sensory aphasia. X-rays showed a 4 x 4 cm. craniectomy site in the left tempor-parietal area (Fig. 77).

On admission to the Military Hospital for Head Injuries on 31st January, 1953, he was dysphasic but was able to give some account of his injury. The R.A. was a few seconds; the P.T.A. 10 days.

There was no dyspraxia, but marked receptive and expressive dysphasia with dyslexia and dysgraphia. He was unable to follow moderately complicated commands, and had difficulty in reading individual words and in making sense of them. His spontaneous speech was telegraphic. He did very simple calculations correctly. He was fully orientated. There was a right homonymous hemianopia, complete in the upper quadrants. The right pupil was larger than the left but both reacted to light and accommodation.

An A.E.G. was unsatisfactory due to the presumed escape of air from the ventricular system through the amputated left temporal pole. The anterior part of the left lateral ventricle was normal in size and position, and the third ventricle was in the midline.

An E.E.G. showed gross slow waves in left temporal leads. By 21st April there was some improvement in his dyslexia and in his ability to understand spoken commands. He could read a few sentences. His dysgraphia was unchanged.

He was examined by the author on 20th March, 1953, when mental testing was carried out (Fig. 78). His scores were: H.R.V. 11 (when read out); no attempt on own reading; Matrices 37; H.R.T. 8 (read to him); Dominoes 18. The H.R.V. and H.R.T. were repeated without help on 27th April; he was still unable to read the H.R.V. and his attempt on the H.R.T. gave him a score of 5.

On Army entry on 21st April, 1951, his score on the Dominoes was 19 (S.G. IV); his present performance (18) showed a fall of one point. His S.G. on the Matrices (IV)

was also consistent with his overall S.G. on Army entry which was V. His performance on a <u>verbal</u> test on Army entry graded him S.G. V.

When visited by a social worker in August, 1953, the dysphasic difficulty was still marked, and he still found it difficult to read and to find the words he wants to express himself.

It should be noted that all these cases were <u>left</u> hemisphere wounds. Their principal anatomical and neurological features are summarised in Table XII.

	L. parietal	+		
	L. parietal to L. occipital	+		
	L. fronto-parietal	+	+	
	L. fronto-parietal	+	+	+
	L. temporo-parietal	+	+	+

It is not proposed to enter into a discussion of the complex problems associated with aphasia, but we do consider the features presented by these 10 cases, in addition, other cases in the series will be drawn upon to amplify certain points.

TABLE XII. PRINCIPAL ANATOMICAL AND NEUROLOGICAL FEATURES IN 10 CASES WITH CLINICAL EVIDENCE OF DYSPHASIA.

Case No.	Site	Motor Loss	Sens. Loss	Vis.Fld. Defect	Handedness
(a) Cases with Consistent Vocabulary Scores.					
32	L. frontal to L. thalamus	+	+	0	R.
49	L. fronto-parietal	+	+	0	R.
(b) Cases with Low Vocabulary Scores.					
20	L. frontal to L. post.-parietal	+	+	0	R.
21	L. parietal to L. frontal	+	+	0	R.
24	L. fronto-temporal to parietal	+	+	0	L.
25	L. parietal	+	+	+	R.
26	L. parietal to L. occipital	+	0	+	R.
27	L. fronto-parietal	+	+	0	R.
33	L. fronto-parietal	+	0	+	R.
62	L. temporo-parietal	0	0	+	R.

It is not proposed to enter into a discussion of the many complex problems associated with aphasia, but merely to consider the features presented by these 10 cases. In addition, other cases in the series will be drawn upon to amplify certain points.

In all these cases there was a clinically observable expressive difficulty, and it will be recalled that this was the basis on which the cases in this group were selected. The expressive difficulty varied from being very obvious

in certain cases to being no more than a slight hesitancy and difficulty in word-finding in others.

When the vocabulary scores of these patients are considered, it is seen that in 8 of them the level of performance on the vocabulary was below that expected from the performance on the problem-solving tests. There was therefore a difficulty in relating a word to its synonym when presented with alternatives (which is the basis of the H.R.V.). This difficulty was found in different degrees and generally increased as the words became more unfamiliar. This defect in the organisation of speech falls into the category of nominal aphasia (Head, 1926), word-meaning aphasia (Wortbegriffsaphasie - Kleist, 1934), or amnesic aphasia (Goldstein, 1948; Nielsen, 1946). We are dealing presumably with the same type of defect when on the one hand we have no obvious failure on such a test as the H.R.V. but only an occasional difficulty in word-finding in spontaneous speech, and on the other hand when the performance on a vocabulary test falls well below the patient's expected level.

The Anatomical Basis of Nominal (Amnesic) Aphasia. (In the following account the cortical areas are those according to Brodmann.)

Head (1926) localised his nominal aphasia to the region of the angular gyrus (Area 39) of the dominant hemisphere, while Kleist (1934) favoured the posterior temporal region

(Area 37 and the posterior part of Area 21). Dandy (1931), in cases of temporal lobectomy, showed that nominal aphasia was a consequence of the removal in the dominant hemisphere, although Penfield and Rasmussen (1950) showed, again in the dominant hemisphere, that the anterior part of the temporal lobe could be removed without any effect on speech. Williams (1945) has described a case with a focal lesion in the region of Area 37 with nominal aphasia.

Weisenburg and McBride (1935) in their extensive study of aphasia separated an "amnesic" group from their expressive and receptive groups. They regarded amnesic aphasia as arising from any fairly extensive lesion in any part of the dominant hemisphere, although their 5 cases had all temporo-parietal lesions, with a homonymous hemianopia in 4.

Goldstein (1948) regards amnesic dysphasia as an indication of diffuse cerebral damage, but if any part of the frontal lobes is sufficiently damaged then it may occur. As a focal phenomenon it is mainly associated with lesions of the temporo-parietal area.

Nielsen (1946) regards the posterior parts of the first, second and third temporal gyri (Area 37 and the posterior parts of Areas 21 and 22) as the "language formulation area" and considers the most typical cases of amnesic dysphasia are due to lesions of this part of the temporal lobe. Amnesic dysphasia, in his opinion, may

also occur with lesions of the angular and supramarginal gyri in a certain proportion of cases. He considers it only a theoretical possibility, however, that a lesion in Broca's Area (44) should ever cause it.

Suter (1953), in a recent paper on what he terms "anomic aphasia", defines a large area of the dominant hemisphere consisting of the supramarginal gyrus, the angular gyrus, and the posterior part of the temporal lobe (Areas 40, 39 and 37) as the anatomical substratum of word-meaning aphasia. He points out that in most cases of amnesic aphasia there is an associated homonymous hemianopia, as shown in the cases described by Head, Weisenburg and Goldstein. He considers this evidence of a temporo-parietal location for this type of dysphasic defect, and in his own series of 20 cases (of vasoular and neoplastic pathology) he reports visual field defects in 70 per cent.

Penfield and Rasmussen (1950), in their studies of the electrical stimulation of the exposed human cortex, have defined in the dominant hemisphere three areas of "aphasic arrest". The essential feature of the stimulation of these areas is that the patient becomes aphasic but not wordless, unable to remember the name of an object shown to him, or becomes confused and uses words quite wrongly. One area corresponded to Broca's speech area (44) in the frontal lobe, one to the posterior part of the temporal lobe (21 and 22), and the other to the supramarginal and angular gyri (Areas 40 and 39).

Owing to the nature of the injuries it is difficult to draw conclusions of focal significance from the lesions in the 10 cases described above; it is certain, however, that the areas described by Penfield and Rasmussen have all been involved or undercut in this group. One point of interest seems to emerge: as the lesions pass into the middle and superior aspects of the frontal lobes, further away from the actual speech areas (as in Cases 49 and 27), the vocabulary scores approach more normal levels. In this respect Case 17 (Group Ib) should be recalled. This right-handed man with a left posterior frontal wound gave a clear history of occasional difficulty in word-finding, especially when emotionally disturbed, yet was able to produce a high score (39) on the W.R.V.

It is realised that some of these cases (from Korea) are of fairly recent origin, and some improvement may naturally be expected. There is sufficient evidence, however, from the older cases to indicate that mostly a permanent disturbance of word organisation has resulted.

Dysphasia and Intelligence.

It would seem improbable on general principles that a dysphasic defect, even one with an extensive loss in word-meaning, should necessarily result in a defect of general intelligence, if by general intelligence we mean the sort of function which comes into play in problem-solving.

In the primates, and in animals very much lower down

the evolutionary scale, problem-solving or "insight-learning" in the Gestalt formula (Kohler, 1925) goes on in the absence of language function, or where it is only primitively organised. Part of the confusion arises from the identification which has been made by certain linguists, notably Müller (1887), between language and thought. As Humphrey (1951) has pointed out, modern experiments have shown that concepts are possible without words.

It was Pierre Marie (1906) who first postulated that aphasia was a defect in general intelligence associated with a special language disorder. This view has been accepted by some modern workers such as Hebb (1949) and Goldstein (1942). It will be recalled that intellectual defect in Goldstein's formulation was a loss in the power to abstract as shown by specific tests, and he associates this loss with amnesic aphasia.

Head (1926) considered aphasia to be a disorder of symbolic formulation and expression, but did not feel that general intelligence and memory were primarily affected. This is also the view held by Weisenburg and McBride (1935):

> "The extent to which intelligence may be said to be affected is a moot point. Some investigators have held that intelligence suffers because speech is disturbed, while others have held that speech is disturbed because of the intellectual disorder.
>
> Much naturally depends upon the definition of intelligence, but it is clear that aphasia does not involve a 'general intellectual defect' such as Marie postulated in addition to the special defect of language. As the majority of authors since Broca have maintained, the clear-cut aphasic patient does not show a general diminution in intelligence. Marie

> was wrong in maintaining that aphasia was in any way a general defect of intelligence, but was right in his belief that other types of mental functioning beyond the language might be affected ..... that intelligence suffers in so far as the language processes disturbed are necessary to the carrying out of intelligent behaviour, and second in so far as non-verbal activities are handicapped by changes in mental functioning which extend beyond language processes and are not dependent upon them."

This view has been put even more strongly by Kennedy and Wolf (1936):

> "We believe there is a distinction between intellectual defect and aphasia, that thought is possible without speech or words, that defective speech can exist as something apart from intelligence, ideation, attention, memory and powers of association. Although thought processes are frequently affected in aphasics, especially with large lesions, it is no more fitting to regard 'Mind' and speech as one than it is to expect every moron to be aphasic."

The 12 cases described above amply confirm that this latter view, as expressed by Weisenburg and McBride and by Kennedy and Wolf, is substantially correct. In spite of the loss in word-meaning, most of the 10 cases performed on problem-solving tests at exactly the level which would have been expected before injury, provided of course that allowance is made for the tests being interfered with in certain cases by a breakdown in symbolic formulation of either a verbal or calculating type. Only in Case 21, and possibly in Case 49, was there a suspected deficit in problem-solving ability. In Case 21 it would be adequately explained by the severe nature of the wound.

In 4 of these cases pre-injury test results were available, and these are summarised in Table XIII, where they provide a convincing demonstration.

TABLE XIII. TEST RESULTS BEFORE AND AFTER INJURY IN 4 CASES WITH NOMINAL DYSPHASIA.

Case No.	Before Injury Dominoes Score	Before Injury Dominoes S.G.	Before Injury Overall S.G.	After Injury S.G. on Matrices	After Injury Dominoes Score	After Injury Dominoes S.G.	Remarks
20	22	IV	III-	III-	11	V	Dyscalculia
24	22	IV	IV	III-	18	IV	-
26	-	-	IV	III-	20	IV	-
62	19	IV	V	IV	18	IV	-

Dysphasia and Cerebral Dominance.

The importance of the left hemisphere for speech function in the right-handed person is an accepted fact, and in the above 12 cases of left hemisphere wounds 11 of the patients were predominantly right-handed. It might reasonably be expected that in people with a clear natural left handedness the right hemisphere would assume a similar importance in their speech function. In a recent paper by Humphrey and Zangwill (1952a), based on records at the Military Hospital for Head Injuries of similar cases to those described in this thesis, it was found that of 10 carefully selected cases of unilateral brain lesion (5 left-sided and 5 right-sided) in naturally left-handed people dysphasia was present in all the cases of left hemisphere injury and in all but one of the right hemisphere cases. The dysphasic symptoms were more severe in the former group, although defects of calculation were more prominent in the latter.

In the present group of 70 cases there were only two patients who had a clear natural left handedness. In both cases the wounds would reasonably have been expected to produce dysphasia. The cases are No. 56 (Group Ia) and No. 24 in the present group.

Case No. 56, it will be recalled, had a very extensive right parietal to right frontal wound, produced a good vocabulary score (27), had a clear intellectual deficit to problem-solving tests, and had no clinical evidence of dysphasia at any time.

Case No. 24, with a left fronto-temporo-parietal wound, had marked dysphasia with a substantial nominal defect.

In both these left-handed cases it would appear that speech function was represented in the left hemisphere.

Dyscalculia and Cerebral Dominance.

In discussing those cases with doubtful intellectual impairment (Group III) there was evidence that patients with severe left-sided parietal wounds did relatively less well on the Dominoes Test as compared with the Matrices, and it was indicated that this was probably due in some degree to interference with the performance on the Dominoes from an element of dyscalculia. There are, however, in the series 3 cases with well substantiated evidence of dyscalculia, based on a significant fall in the Dominoes score since injury, on the spontaneous history of the patient, or on the evidence of performance on simple calculations.

Two of these cases (Nos. 9 and 57) are from Group IIIa and one (Case 20) is from the present group. The relevant features of these cases are summarised in Table XIV.

TABLE XIV. CERTAIN RELEVANT FEATURES IN 3 CASES WITH DYSCALCULIA.

Case No.	Fall in Dom. pts.	Nature of Injury	Description of Calculating Defect	Hemisphere	Handedness
9	7	Metallic fragmt. R. post.-pariet. region to L. ant. parietal region	"Not so good at sums"	R & L	R
20	11	Metallic fragmt. L. frontal to deep L. post.-parietal	Wrote down & named correctly all figs. from 1-10. Counted a sum of money correctly. Added a simple sum correctly. Multiplied 371 x 13 correctly. Was unable to subtract 3402 from 4718 (2 from 8 = 9)	L	R
57	10	Severe lacern. L. parietal cortex beneath gutter-type depr. fr.: dural defect 6 x 1.5 cm. Also bone fragmt. indriven 4-5 cm. into parietal lobe towds. motor area	(Early disturbance of body image) Difficulty in forming & recognising certain figures	L	R

Defects in calculation following brain disease were first systematically described under the term "acalculia" by Henschen in 1920.

The variable nature of the calculating disturbances which might arise has been frequently demonstrated; complex factors are obviously involved, and some of these have been

analysed recently by Grewel (1952).

The cases described above illustrate some of the features which have been described. In Case 20 there was no difficulty in recognising and naming individual figures, a sum of money could be counted quickly and accurately, simple addition and muliplication were done correctly, but when a simple subtraction sum was presented he was unable to do it. He may have been unable to decide whether 2 was greater or less than 8, or he may have lost the meaning of the subtraction operation altogether.

In Case 57 there was a distinct loss in the ability to form figures or in recognising their meaning; the symbol for 2, for example, had lost its meaning, and when asked to write down a 2 he didn't know how to do it without much hesitation.

All areas of the brain have been implicated in acalculia, but the most typical defects such as those described above occur with parietal lesions, although of course the part played by the frontal lesion in Case 20 is uncertain.

The point of real interest which has arisen out of this investigation, as far as dyscalculia is concerned, has been the sensitivity of the Dominoes Test to calculating disturbances. Henschen emphasised the visual factor, while Humphrey and Zangwill (1952b) have also commented on the difficulty in revisualising numbers and the loss of imagery of numerical form. The visual factor would seem to be an important one in the Dominoes Test, where several sets of

dots in a single example have to be counted and converted into numbers and retained.

Some relation to cerebral dominance can be seen in 2 of these 3 cases. Cases 20 and 57 were both left hemisphere wounds in/predominantly right-handed men. Unfortunately, there were no right-sided parietal wounds of similar position and severity to form a comparable group, but comparison with Humphrey and Zangwill's (1952a) series of dominantly left-handed men is of interest. In that group defects of calculation were significantly more prominent in the wounds involving the right hemisphere. There is therefore suggestive evidence that calculation follows handedness in its cerebral dominance much more consistently than does speech. It will also be recalled that in Case 1 (Group Ia), where the left parietal area was involved in a right-handed man, there was also a spontaneous account given by the patient of difficulty with numerical memory.

IV. DISCUSSION.

Owing to the extensive nature of the data presented in this thesis, most of the special features have been discussed as they arose in the presentation of the results. It now remains to summarise and correlate these findings.

It is necessary, first of all, to consider some general points. Traumatic material has been criticised because exact information as to the site and extent of the lesion is not available until after death, and any conclusions drawn in life, even if based upon excellent surgical and radiological evidence, as was the case in this series, must necessarily be tentative. This fact is fully accepted, but it is pointed out that no material, not even leucotomy material, is free from defects of this sort. Traumatic material, providing as it does a usually non-progressive lesion, is probably freer from these defects than most, and is certainly more satisfactory than some (e.g., neoplastic material).

Russell (1932) in discussing cases of closed head injury has suggested that the duration of the post-traumatic amnesia (P.T.A.) gives an indication of the amount of brain damage in such cases. It should be noted that in this series, although it was true that cases with recognisably severe and extensive injuries (such as those in Group Ia) had prolonged amnesia, it is equally true that some cases in which no intellectual deficit could be demonstrated also had prolonged

amnesias. It has been suggested by the author elsewhere (Jarvie, 1954) that a prolonged P.T.A. may be an indication of damage to specific (e.g., diencephalic) mechanisms concerned with consciousness, as described by Jefferson (1944) and Cairns (1952).

Factors such as post-traumatic epilepsy are so equally distributed over the series that their effect in producing disturbance of intellectual functioning must be regarded as negligible. The same applies to cases seen several years after injury where deterioration not due to the actual wound might be postulated as causing at least part of the defects; here the patients did either well or badly, the only significant factor being the nature of the injury.

The method employed to estimate the defects could be criticised, but it is pointed out that every care has been taken not to draw unwarranted conclusions from these mental test results; moreover, in 31 of the 70 cases accurate information about the intellectual level of the patient before injury was available.

It might also be argued that failure on the problem-solving tests was not due to any general intellectual deficit as such but to a breakdown in the appreciation of the symbolism employed in each test; the consistent failure on each test in certain cases might be due to the fact that each type of symbolism was affected equally. This is highly improbable, although it has been shown (in cases with dysphasia and dyscalculia) that such a selective

breakdown may indeed affect performance on a specific test. In the cases showing an unequivocal deficit (Group I) the absence of clinical evidence that each type of symbolism (verbal, calculating and visual-spatial) was affected would indicate that a general factor was mainly responsible for the deficiency in performance. It cannot be pretended, however, that the interpretation of the results has invariably been easy.

It will be recalled that in the introduction the main problem posed in this study was "What kinds of injury produce a loss in relating activity as demonstrated by performance on problem-solving tests?". Although, as has been indicated, there are several cases of doubtful significance in this series, one thing is clear: that the most extensively destructive wounds (Group Ia) all showed an unequivocal deficit on each problem-solving test administered. To this number can be added Case 21 of Group IV. In these 4 cases an extensive disruption of the fibres passing between the frontal and parietal areas must have taken place. It has been suggested that in this type of injury the long association tracts (especially the superior longitudinal fasciculus) are involved.

On the other hand, it is quite clear that where the injury is represented by no more than a depressed fracture causing perhaps an underlying area of cortical contusion or softening, then no deficit results; indeed, in such cases (Group IIIa) scores on mental tests may actually rise in a similar manner to that observed on re-testing the normal controls.

The wounds of Group Ib are of special interest because they are relatively localised and pass deeply into the hemisphere in the mid-posterior frontal and mid-anterior parietal regions. It is again suggested that they have produced their effect by interrupting fibres which are concentrated in this area in their passage between the frontal and parietal lobes.

Nevertheless, intellectual functioning, in the special sense in which it has been demonstrated in this investigation, may remain relatively intact in the presence of severe wounding. This seems to be particularly true of the frontal lobes, where extensive damage to the frontal poles or to the anterior parts of the frontal lobes generally may result in little or no alteration in performance on problem-solving tests. This confirms previous findings, of which the studies of Hebb and Penfield (1940) on frontal lobectomy and Struckett (1953) on pre-frontal leucotomy have already been mentioned.

An erratic performance on testing was a common finding in the frontal lobe cases in the early weeks or months after injury; this was readily recognised, and the patients could correct their scores adequately. The importance of the time factor in testing after injury or after surgical interference has also been emphasised by Struckett (1953).

Many puzzling features remain. Wounds passing into areas where some effect on intellectual functioning might be expected (such as the posterior frontal region) produce uncertain or no changes on problem-solving tests. In the absence

of accurate pathological evidence it can only be assumed that the direction or destructive effect of these wounds is such that they do not interfere vitally with pathways concerned in problem-solving activity.

It is equally difficult to reconcile the clear, unequivocal deficits which occurred in the extensive wounds described in Group Ia with reports of hemispherectomy, in which no deficit in intellectual functioning has been found (Rowe, 1937) and where scores even rose after the operation (Cairns & Davidson, 1951). In Rowe's case no details of testing are given; the difficulty of drawing conclusions concerning deficits in problem-solving activity in a novel situation by using tests of the Binet-Simon type (which depend so much on acquired experience) has already been emphasised. In one of the cases described by Cairns and Davidson (1951), however, the point score on the 1938 Matrices rose from 19 before operation to 53 a year after operation. In this case the hemisphere was removed for infantile hemiplegia. It can only be speculated that this hemisphere was exerting an adverse effect on the function of the other, the latter having from the beginning taken over most of the functions which normally would have been shared with the damaged hemisphere.

When these wounds enter the parietal area they enter a region intimately concerned with perceptual and symbolic appreciation; here calculation, verbal capacity and visual-spatial orientation are represented. Consequently, careful

interpretation of the test results is required, as performance becomes selectively affected by the breakdown of these various symbolisms.

It is obvious that no problem will be solved if it is set in a medium the symbolism of which has never been acquired or has been lost. Yet when an appropriate medium is selected, problem-solving activity may function effectively, providing there is no defect of a general character. On the other hand, where there is such a defect the complete functional autonomy of the symbolism may be preserved (as that of speech in Case 8), but as soon as the symbolism is converted into a specific problem which requires "thinking out" then the problem, depending on its complexity, cannot be effectively completed.

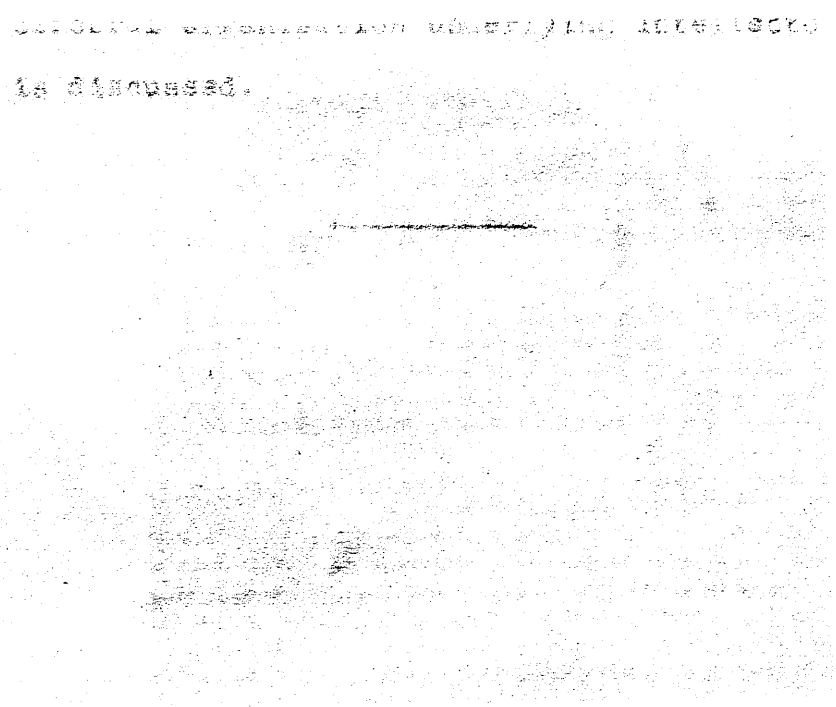
Most of the cases which showed a severe loss in problem-solving activity did not by any means show a mental picture similar to organic dementia. The cause of this is obvious: these men had a vast amount of acquired experience still intact upon which they could draw, and it was only in attempting a new task that their defects became apparent. Similar injuries in childhood would undoubtedly have produced mental retardation.

It has seemed most reasonable to regard the results of these injuries on problem-solving activity as being due to the interruption of deep white fibres rather than to the destruction of the specific areas of cortex underlying the wounds. In the first place, anatomically the white fibres

were more affected than the cortex, as far as one could tell; and, secondly, the cerebral activity involved in a problem-solving task is almost certainly due to the coordination of the activities of various functional areas, and the more effectively a specific area is isolated by the destruction of its communicating fibres the less effective its contribution will be. It is recognised, as noted above, that the parietal area is concerned with the appreciation of the different types of symbolism involved in these tasks; it is less easy to see what the special function of the frontal lobes in this respect might be. As Le Gros Clark (1948) has pointed out, there is little anatomical evidence to support the once prevalent view that the frontal lobes are a kind of "super-association area", and their close functional relation with the thalamus and hypothalamus is increasingly recognised. It may be that in the problem-solving task they add the emotional stimulus which aids the problem to "click" into place.

The results of this study would hardly support the view that there are areas of high specificity, especially within the frontal lobes, where "intelligence" is represented. There are, however, areas of relative autonomy where "intellectual" functions such as speech and calculation have their basis. These intellectual functions develop under the influence of intelligence, but when they are disturbed after injury this does not mean that intelligence, at least in the sense of relating activity, is correspondingly affected.

How far one is justified in making comparisons with the results of experiments in animals, where the cerebral organisation is so different from that in man, is questionable, but certain similarities can perhaps be seen between the conclusions reached in this thesis, based as it is on unique human material, and those of Lashley (1929, 1950) based on the primates and the rat.



V. SUMMARY.

1. The results of the application of a series of "problem-solving" tests to a group of 70 men who had sustained penetrating brain wounds are analysed.

2. The types of injury which produced deficits in this problem-solving capacity are described.

3. The effect of the injuries on other types of intellectual functioning is considered.

4. The relation of these findings to the nature of the cerebral organisation underlying intellectual activity is discussed.

APPENDIX A.

RANK, AGE, UNIT, SERVICE TRADE, CIVILIAN OCCUPATION, AND THE RESULTS OF MENTAL TESTING OF THE 50 NORMAL CONTROLS

1	2	3	4	5	6	7	8	9
Control No.	Rank	Age	Unit	Service Trade	Civilian Occupation	H.R.V.	Matrices	H.R.T.
1	A.C.	20	R.A.F.	Driver	House-painter	19	46	16
2	Ldng.Airmn	18	R.N.	Air traffic controller	Ceramic printer	29	45	17
3	Pte.	19	R.A.O.C.	Driver	Electrician	19	32	9
4	Pte.	19	R.A.O.C.	Storeman	Labourer	18	32	7
5	Pte.	18	R.A.O.C.	Storeman	Lorry-driver's mate	24	41	12
6	Pte.	20	R.A.S.C.	Driver	Carpenter	25	47	16
7	Sgt.	22	R.A.E.C.	Instructor	Trainee teacher	37	52	17
8	A.C.	21	R.A.F.	Photographer	Photo-engraver	34	51	18
9	Spr.	19	R.E.	Clerk	Clerk	28	45	17
10	Pte.	19	R.A.O.C.	Clerk	Apprentice printer	33	50	17
11	P.O.	28	R.N.	Radio mechanic	Physical training instructor	37	56	20
12	Sgt.	21	R.A.E.C.	Instructor	Civil servant	39	52	17
13	Pte.	20	R.A.O.C.	Storeman	Packer	12	29	7
14	Pte.	18	R.A.O.C.	Storeman	Crane driver	28	36	15
15	Pte.	20	R.A.O.C.	Storeman	Butcher	20	36	12
16	A.C.	23	R.A.F.	Mechanic	Printer	30	39	19
17	Sgn.	19	R.Signals	Linesman	Textile worker	28	43	16
18	Sgt.	35	R.A.	Gunnery instructor	*	33	43	10
19	Pte.	21	R.A.O.C.	Storeman	Gardener	14	39	10
20	Sgn.	21	R.Signals	Driver	Steel worker	19	43	12
21	Pte.	19	R.A.O.C.	Storeman	Machine operator	22	34	11
22	Pte.	21	R.A.O.C.	Storeman	Plumber	25	32	9
23	Pte.	18	R.A.O.C.	Storeman	Shop assistant	26	34	9
24	Pte.	19	R.P.C.	Orderly	Labourer	15	23	4
25	Pte.	18	R.A.O.C.	Storeman	Potter	23	48	12
26	Pte.	18	R.A.O.C.	Storeman	Nurseryman	23	41	14
27	Pte.	20	R.A.O.C.	Clerk	House-painter	29	47	14
28	Cpl.	19	R.E.	Printer	Lithographic printer	33	49	13

1	2	3	4	5	6	7	8	9
29	Pte.	18	R.A.O.C.	Storeman	Coalman	21	35	12
30	Pte.	21	S. Wales Brderers.	Mess waiter	Farm labourer	25	44	13
31	Pte.	18	R.A.O.C.	Storeman	Labourer	20	46	16
32	Spr.	18	R.E.	Draughtsman	Quantity surveyor	34	52	18
33	Spr.	19	R.E.	Crane driver	Plumber's mate	33	43	17
34	Sgn.	19	R. Sigs.	Switchboard operator	Apprentice fitter	22	36	11
35	Pte.	19	R.A.O.C.	Storeman	Case-maker	27	40	13
36	Cpl.	22	R.E.	Surveyor	*	33	56	18
37	Pte.	20	R.A.S.C.	Driving instructor	Bank clerk	31	53	17
38	Pte.	19	R.A.M.C.	Cook	Cook	18	27	5
39	Pte.	19	R.A.S.C.	Driver	Bricklayer	24	42	14
40	L/Cpl.	34	R.E.M.E.	Driver	*	34	48	17
41	L/Cpl.	22	R.E.M.E.	Mechanic	Production engineer	36	54	18
42	Pte.	20	R.A.O.C.	Clerk	Steward (Merchant Navy)	30	48	19
43	Pte.	18	R.A.O.C.	Storeman	Enamel sprayer	14	26	4
44	Pte.	20	R.A.O.C.	Storeman	Lead glazer	22	42	14
45	Cfn.	20	R.E.M.E.	Welder	Welder	33	44	11
46	Fus.	21	R. Fus.	Rifleman	Plumber	32	50	18
47	Pte.	18	Ox.& Bucks.	Rifleman	Apprentice photographer	32	54	17
48	Pte.	18	R.P.C.	Orderly	Gardener	26	24	9
49	Sgn.	28	R. Sigs.	Driver	Labourer	27	34	7
50	Pte.	19	G.Howards	Rifleman	Bricklayer	14	35	5

*Where no civilian occupation is given, the man has been a regular soldier since he was a boy.

APPENDIX B.

RESULTS OF PRESENT TESTING AND ON ARMY ENTRY, WITH THE DOMINOES TEST, IN TWENTY-SIX NORMAL CONTROLS

Control No.	Army Score	Present Score	Plus (+) Difference	Minus (-) Difference	Testing Interval (months)
25	30	32	2		2
26	31	34	3		4
27	40	34		6	20
28	32	34	2		13
29	25	25	-	-	5
30	28	34	6		13
31	40	35		5	6
32	40	36		4	9
33	32	35	3		10
34	25	27	2		20
35	21	28	7		18
36	37	44	7		50
37	36	42	6		21
38	10	13	3		18
39	26	25		1	10
40	34	35	1		24
41	39	39	-	-	13
42	38	42	4		4
43	21	18		3	5
44	29	42	13		22
45	28	30	2		22
46	31	37	6		12
47	31	39	8		1
48	17	24	7		5
49	22	22	-	-	10
50	16	6		10	3

APPENDIX C.

POINT SCORE EQUIVALENTS OF THE (SELECTION) GRADES IN THE 1938 PROGRESSIVE MATRICES AND THE DOMINOES TEST (AT AGE 20)

(S.)G.	Matrices From	To	Dominoes From	To
I	60	55	48	40
II	54	49	39	33
III* +	48	45	32	28
-	43	38	27	23
IV	37	24	22	14
V	23	0	13	0

*Grade III (mentally average) is divided into two sections depending upon whether the score is greater or less than the median score (G. III+ or G. III-). In the Matrices the median score is 44, and G. III scores above this are +, below it -. No actual median score is given for the Dominoes, but a distinction is still made in G. III into + or - scores

APPENDIX D.

M.R.C. INDEX NUMBER, RANK, AGE AT WOUNDING, DATE OF WOUNDING, DATE OF TESTING, CIVILIAN OCCUPATION BEFORE WOUNDING SITE OF WOUND, AND THE RESULTS OF MENTAL TESTING AFTER & BEFORE WOUNDING (WHERE AVAILABLE) IN 70 CASES

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Case No.	MRC Index No.	Rank	Age at Wounding	Date of Wounding	Date of Testing	Civilian Occupation (before wounding)	Site of Wound	TEST RESULTS (after wnding) HRV	Mat.	HRT	Dom.	(before wnding) Matr.	Dom.
1	959	Cpl.	23	24. 4. 51	20. 3. 52	Draughtsman	L. parietal to R. frontal	33	34	7	20	48	
2	203	Pte.	18	6. 8. 44	31. 8. 52	Clerk	R. frontal	26	28	6			
3	188	Cpl.	24	4. 8. 44	19. 2. 52	Postal clerk	L.- R.frontal	38	51	17		S.G.I	
4	968	Pte.	20	18.11. 51	10. 3. 52	Farm labourer	R.- L. frontal & L.parietal	22	48	15	28		
5	966	Fus.	36	3. 1. 51	24. 3. 52	Heavy transport driver	R. frontal	32	26	3			
6	753	Gnr.	23	5. 4. 45	2. 4. 52	Labourer	R.-L. frontal	20	36	7			
7	961	Sgt.	25	24. 1. 52	7. 4. 52	Farm labourer	L. frontal	21	40	7			
8	928	Sgt.	34	5. 3. 48	10. 4. 52	*	R. frontal to R. parietal	34	15	2	18		
9	962	Pte.	20	19.11. 51	21. 4. 52	Galley boy	R.-L.parietal	22	30	5	15		22
10	964	Pte.	20	19. 2. 51	24. 4. 52	Shoreman	L. frontal	30	44	15			32
11	893	Gdsmn	20	20. 4. 45	6. 5. 52	Gas-fitter	L. parietal	37	42	15	20		
12	960	Cpl.	30	3. 1. 51	19. 5. 52	Clerk	R. frontal	35	35	11			

1	2	3	4	5	6	7	8	9	10	11	12	13	14
13	950	Pte.	19	17. 11.51	12. 6. 52	Labourer	L. parietal	18	39	12	29		19
14	969	Pte.	20	2. 2.52	13. 6. 52	Bargee	L. frontal to R. parietal	26	33	13	22		26
15	621	Sgt.	25	19. 2.45	26. 6. 52	Butcher	L. frontal to R. parietal	36	45	18			
16	967	L/Cpl.	22	15. 4.52	2. 7. 52	Boiler-maker	L. frontal	29	41	16	28		33
17	963	Cpl.	29	14. 3.44	7. 7. 52	Sanitary inspector	L. frontal	39	35	10	23		
18	978	Pte.	20	11. 2.52	7. 7. 52	Farm labourer	L. temporal	17	33	12	32		23
19	965	Cpl.	23	1. 11.44	8. 7. 52	*	R. & L. frontal	33	40	13	41		
20	977	L/Cpl.	19	5. 5.52	9. 7. 52	Tailor's cutter	L. frontal to L. parietal	15	39	8	11		22
21	706	Pte.	33	19. 8.44	11. 7. 52	Steel-worker	L. frontal	7	21	1	3		
22	120	Dvr.	36	15. 7.44	30. 7. 52	Bus conductor	R. frontal to R. occipital	30	39	13	19		
23	980	Pte.	19	23. 6.52	6. 8. 52	Labourer	L. frontal	19	34	4	24		24
24	976	Pte.	18	23. 7.52	21. 8. 52	Van-boy	L. temporal	0	43	11	18		22
25	6	Mn.	20	17. 6.44	7. 8. 52	Labourer	L. parietal	16	50	9	27		
26	981	Pte.	19	24. 4.51	13. 8. 52	Labourer	L. parietal to L. occipital	15	40	4	20		S.G.IV
27	54	L/Cpl.	20	28. 6.44	18. 8. 52	Shop assistant	L. frontal	21	45	13	24		

1	2	3	4	5	6	7	8	9	10	11	12	13	14
28	982	Cpl.	24	26. 5. 52	20. 8. 52	Fitter	R. parietal	36	32	13	25	S.G.III-	
29	585	Drvr.	27	10. 2. 45	21. 8. 52	Cutler	R. frontal	31	32	5	30		
30	132	Spr.	29	18. 7. 44	26. 8. 52	Shoemaker	L.-R.parietal	27	33	4	19		
31	100	Sgt.	32	13. 7. 44	12. 9. 52	Bricklayer	R. parietal	35	33	10	22		
32	805	Capt.	25	18. 4. 45	10. 1. 53	Insurance clerk	L. frontal to L. thalamus	36	47	16	31		
33	417	Pte.	19	20. 7. 44	25. 2. 53	Gardener	L. temporal to L. frontal	7	35	3	20		
34	455	Tpr.	31	12. 3. 44	27. 2. 53	Farm labourer	R. occipital to mid-frontal	13	22	2	9		
35	973	Pte.	19	19.11. 51	30. 9. 52	Painter & decorator	L. frontal	27	43	18	37		34
36	457	Pte.	20	10. 3. 43	2. 3. 53	Plumber	L. parietal	26	41	7	15		
37	986	Pte.	23	10. 6. 44	21.10. 52	Carpet weaver	L. temporal	33	48	15	24		
38	987	Pte.	19	8. 8. 52	28.10.52	Labourer	L. frontal	24	50	14	31		37
39	741	Pte.	19	30. 3. 45	14.10. 53	Bricklayer	R. frontal	21	29	5	17		
40	406	L/Cpl.	25	23.10. 44	12. 6. 53	Storeman	R. frontal	16	25	6	19		
41	990	Sgt.	22	24.12. 51	11.11. 52	*	L. frontal	32	51	17	38		38
42	242	Pte.	20	17.8. 44	18.11. 52	Clerk	L. parietal	32	47	16	24	S.G.IV	
43	882	Rfn.	36	25. 4. 45	16. 3. 53	Textile worker	R. temporal	31	30	8	15		
44	991	Pte.	21	18. 7. 52	16.12. 52	Cinema projectionist	L. frontal	36	51	18	36		S.G.II
45	992	L/Cpl.	20	5.11. 52	7. 1. 53	Apprentice joiner	L. occipital	28	37	12	36		34

1	2	3	4	5	6	7	8	9	10	11	12	13	14
46	926	Pte.	25	13. 11.43	8. 1. 53	Butcher	L. frontal	26	34	12	26		
47	993	L/Cpl.	24	23. 10.52	8. 1. 53	Shipwright	L. frontal	33	48	16	31		32
48	702	Pte.	19	9. 3.45	5. 6. 53	Factory hand	L. parietal	27	45	13	22		
49	889	Sgt.	25	17. 1.45	9. 7. 53	*	L. frontal	25	40	5	20		
50	996	Sgt.	36	19. 10.52	21.1. 53	*	L. fronto-temporal	32	49	14	35		26
51	713	Pte.	20	9. 3.45	26.1. 53	Labourer	L. parietal	25	40	9	17		
52	416	Lieut.	29	22. 12.43	30.1. 53	Shipping clerk	R. frontal	39	48	16			
53	997	Cpl.	22	19.11. 52	9.2. 53	Riveter	L. frontal	14	27	5	21		14
54	405	Fus.	24	26. 10.44	20.2. 53	Carpenter	L. occipital	25	41	13	30		
55	1003	Pte.	19	5. 3.53	29.5. 53	Lorry-driver's mate	R. frontal	16	26	5	20		24
56	1004	Pte.	19	10. 4.53	6.7. 53	Saw-mill labourer	R. parietal to R. & L. frontal	26	21	6	19		29
57	998	Pte.	19	7. 1.53	27.2. 53	Colliery worker	L. parietal	20	37	7	17		27
58	984	Cpl.	26	28. 6.52	18.9.52	*	R.-L. frontal	32	42	13	27		
59	999	Fus.	19	25.11.52	2.3.53	Factory hand	R.-L. frontal	12	31	6	19		
60	1000	Pte.	19	17.11.52	4.3.53	Railway fireman	L. occipital	23	40	13	28		29
61	989	Pte.	19	30. 1.45	6.11.52	Labourer	R. occipital & R.parietal	28	41	12	24		
62	1001	Fus.	20	25.11.52	20. 3.53	Factory hand	L. temporal	11	37	8	18		19

1	2	3	4	5	6	7	8	9	10	11	12	13	14
63	1002	Pte.	22	19.11.52	23. 3.53	Painter & decorator	R. frontal	25	35	15	28		23
64	846	Pte.	20	16. 6.45	11.12.52	Instrument maker	R.- L. frontal	37	33	8	29		
65	O.S.2037	Sgt.	28	24. 6.41	14. 4.53	Farmer	L. frontal	30	36	14	33		
66	466	Lieut.	31	10. 6.44	15. 4.53	Auctioneer	R. parietal	29	56	19	27		
67	994	Pte.	22	19.10.52	14. 1.53	Plumber	R. parietal	23	31	6	15		11
68	226	Pte.	31	18. 7.44	6.10.52	*	L. & R. frontal	24	35	4	18		
69	1005	Pte.	19	27. 5.53	27. 7.53	Woodcutter's labourer	L. frontal	20	29	12	24		22
70	1006	Pte.	19	15. 4.53	5. 6.53	Haulage hand	R. frontal	17	28	4	16		14

NOTE: In the above "site of wound" refers to the actual brain areas involved and not to the position of the skull defect.

"Date of testing" is the date when the patient was first tested by the author.

Where the civilian occupation is indicated by an asterisk (*), this means that the man has been a regular soldier since he was a boy.

APPENDIX E.

GENERAL ANALYSIS OF THE SITES OF WOUNDING IN 70 CASES

Cerebral Area	Hemisphere	No. of Cases	TOTALS
Frontal	Right	10	
	Left	17	
	Bilateral	7	34
Parietal	Right	4	
	Left	8	
	Bilateral	2	14
Occipital	Right	0	
	Left	3	
	Bilateral	0	3
Temporal	Right	1	
	Left	4	
	Bilateral	0	5
Others	-	14	14

APPENDIX F.

EXAMPLES OF WRITTEN COMPOSITIONS BY CASE 8.

News from Headington Hill Hall.

It was with much pleasure, and interest, that many of us here received and read your first edition of Neurone News. It is now my privilege to contribute the first news from the Headington Branch of the Neurological Unit. Many of the patients here have spent a period at Stoke Mandeville Hospital. Most of us who were there had the privilege of having the skipper on the Bridge of 5 x. Now that you have moved to 10 Ward to be nearer the ladies, it is hoped you will remember Kitchener's Order to the first 100,000

"Treat all women with courtesy."

It is not my intention to be honoured here as a philosopher but rather to honour philosophy by trying to lead a virtuous life.

In this small world of ours here, it is very large in experience, seldom has such a small community such a variety of interests and one need never be lonely or bored. In any case a sensible man should have enough company in himself, but friendship is a great thing to us. I cannot do better than express this in the words of Blair

Friendship mysterious cement of the soul,
Sweetner of life, soldier of society,
I owe thee much.

As in all communities it is sometimes difficult to retain one's individuality but the congenial way all get on although views are vastly different, sometimes I think that all of us believe that the noblest work of creation is an honest man, and our ambition is to obtain that.

Time has to be occupied here as in every place. Each individual is responsible how it is occupied. There is a working week from Monday till Friday of four hours each day, with a half-day on Wednesday, during that time, everyone does some sort of occupational therapy. There is quite a variety, Gardening, Carpentry, French Polishing, Weaving, and the latest thing, which seems to be very popular is cane work, making baskets, lampshades, and Cutlery boxes.

That leaves quite long evenings and Week-ends which have to be occupied as time does not pass or fly, but we

seldom appreciate the fact that we pass it, and Father Time is always there. All of us who can get around spend at least one evening at the Pictures. Some attend the Football matches regularly, and some are keen supporters of Headington United.

We are fortunate in having a very good television set and there are many keen viewers, as yet I have not heard of anyone developing television cramp here. A few read quite a lot, and there is a very good Library where all tastes in Literature can be satisfied. One very popular fellow occupies his off time fishing or so he says, anyhow he has got rods, lines, nets and baskets, and all the tackle an angler requires. A conversation with him on his hobby can be more interesting and instructive than Izaac Walton's "Complete Angler".

Football and Racing are followed very keenly by some with no small success now and again during the Summer months we had several very good outings to Garden Parties, Races, etc., which were enjoyed very much by all. Now the Winter months are coming there is little doubt but that we shall be well looked after as regards Recreational Functions and amusements.

Now I have given you all the news as far as I know it from Headington Neurologicals will dry up, wishing you every success in your interesting venture and shall be pleased to contribute to you again maybe.

Appendix F. (cont.).

ONE OF OUR SUBMARINES

This Book written by Commander Young must rank as one of the best of Modern "Sea Yarns" Explaining fully the High standard of efficiency as a sailor a man must reach before being accepted in this Branch of the Service also giving full details of the training one has to go through after being accepted for submarine work which is long and very strenuous on the nervous and physical systems.

When one acknowledges how near the Germans got to cutting our sea communications In both the past world wars by the use of Submarines It probably tends to make one read more about the measures that were taken to counteract the U Boat Menace than read about our own submarines.

In presenting this wonderful book The Author tells his story very modestly and in simple language not using too many technical terms although he had to suffer many rebuffs by being only a R N V R from the professional R Ns. He overcame them and was respected by his crews regular and volunteers alike.

It is a story that takes you to all the theatres of the last war on Sea from the British Isles to the Mediterean to the Artic where it was shown how difficult it was to get on with the Russians. In the later part of the war it deals with the operations in the Indian Ocean operating from Ceylon where an incident explaines the treachery of some deserters. It then explains the operation in the South East Pacific operating from Australia in combination with the U S A Navy there work in this theatre is very dull as most of the Pacific Battles has been won by the U S A Navy. The Book Finishes with their return to England where the Author is due to get married and we hope live happily ever after.

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