The Use of a Computer in the Diagnosis of Intracranial Tumours

G. H. du BOULAY

St. Bartholomew's Hospital, London, E.C.1, England

Experiments in the use of a computer as an aid to diagnosis of intracranial tumours have been started at St. Bartholomew's Hospital in collaboration with The City University. The computer can estimate the probability that a patient has any given type of tumour by comparing the results of tests with those obtained in previous patients whose diagnoses have been established. The computer also determines which is the best investigation, from a statistical point of view, to perform next on the patient in order to confirm the diagnosis.

Literature

Korein, Kricheff, and their coworkers (1965, 1966) have described a means of coding and recording information contained in x-ray reports of neurological patients which does not require changing the information into a code of numbers. They also refer to much useful background work by themselves and others. They now have a considerable store of data, but have not gone far in using this method for prospective diagnosis.

The mathematical and statistical backgrounds for such diagnostic attempts were reviewed by Boyle et al. (1966) in their report of a study on the use of a computer in differential diagnosis between simple goitre, Hashimoto's disease and thyroid cancer. Though Boyle's work was concerned with much more limited data than that required in the diagnosis of cerebral tumours, the theory upon which both his and the work at St. Bartholomew's Hospital and The City University rests is the same and has been covered in papers by Jeffreys (1961), Warner et al. (1961), Kendall and Stuart (1963), and Bailey (1965). His approach has given practical and accurate results. Lodwick (1966) has set down some of the steps required in constructing a model for radiological diagnosis of bone tumours.

The large number of basic tests involved has presented some new problems.

Program

Eight physical processes are considered. Each process—plain film or carotid angiography, for instance—corresponds to a comprehensive test, each test itself being divided into basic tests. These total about 400. All the basic tests are individual, defined radiological signs. Plain x-ray examination, for example, provides a total of 88 basic tests, each of which must be considered and then recorded positive or unreadable. Basic tests which are negative are not recorded on the "report form."

Carotid angiography, the second of the comprehensive tests, consists of 68 basic tests. The vast majority of these, again, are small individual signs, but a few of them are of a pantechnicon nature and have a slightly different role in the collection and classification of material.

In the disease classification there are about 172 different entries, this being a topographic as well as a pathological index. There are in all only 19 pathological types. In order to obtain some assistance from clinical signs, the patients are first divided into three groups according to nonradiological evidence. These groups are: (1) perisellar tumours; (2) supratentorial metasellar tumours; and (3) juxta- and infra-tentorial tumours. This simple breakdown is generally accurate and promises greater diagnostic value from individual radiological signs.

The file of information concerning past patients is held on magnetic tape. This consists of the number of patients with each type of tumour on whom each basic test was made and the number that had positive results.

Weighting

Statistical methods of diagnosis have certain limitations. These arise chiefly from the fact that the computer is concerned with the quantities rather than the quality of each basic test. Such limitations may be mitigated by a system of weighting basic tests so that one may be made more important than another.

1. In applying the first statistical model to the diagnosis of new cases, it was at once obvious that, even in Group 1, where most data had been accumulated, the differences in probability separating different diagnoses were very small indeed. An examination of the predictions revealed that this was largely due to the fact that negative results counted equally with

positive results and, of course, far outnumbered them.

Accordingly, it was decided to weight each positive by a factor of 100 as against each negative, thus increasing the effectiveness of positive findings in making a diagnosis. The immediate result of this single first step in weighting was a considerable increase in diagnostic accuracy.

There are other reasons for weighting and different ways of doing it. Two more stages are proposed.

2. Some basic tests, by their nature, must be more significant than others. They are the tests which show the tumour directly, as opposed to those due to secondary displacements of more distant structures. Certain more significant basic tests are therefore given an extra weight. The actual weight to be assigned to these more significant basic tests is now in the process of being calculated.

3. A distinction may be drawn between weighting that is due to the inherent importance of a sign, such as already described, and significance, which may appear unexpectedly due to the frequency with which a distant sign occurs. Because the calculation by the computer upon which a diagnosis is made is a sum of signs, it would be valuable to give extra weight to any sign which appears frequently and exclusively with a particular disease. Such signs will probaby not be included among those derived from Stage 2.

The accuracy of a particular basic test in making a diagnosis of a particular disease should be in some way proportional to its exclusiveness to that disease. It should also be proportional to the frequency with which the sign occurs in that disease (due allowance having been made for the number of cases).

Method of Working

A very simple, duplicated form has been designed. One such form is used for each patient, and the patient is identified at the top by hospital and registry numbers. A patient's diagnosis, when known, is recorded by the code 1, 2, or 3 for supratentorial suprasellar, supratentorial metasellar, and juxta- or infra-tentorial tumours, and, thereafter, by the number which signifies the exact diagnosis. When a new patient is to be assessed, only the clinical group 1, 2, or 3 is put at the top.

The rest of the form consists of divisions, two for each type of examination (here known as Comprehensive Tests 1–8). In one division are written the numbers representing positive basic tests and, in the other, the numbers representing those basic tests which, for one reason or another, have been unrecordable. Unrecordable tests result chiefly from technical failures. The failure of the posterior communicating artery to fill at carotid angiography is one such example.

When each form has been completed, it contains anything from, let us say, 6 to 25 numbers indicating positive observations at plain x-ray and whatever contrast examinations have been completed.

In the computer department of The City University this information is transferred to punch cards. The subsequent operations have already been described up to the point at which an answer is obtained from the computer to the two questions: 1) What is the diagnosis? and 2) What investigation should be performed next in order to confirm this diagnosis?

The answer to the first question is presented as a list, with a figure against each diagnosis indicating probability. Some types of investigation may be inadvisable clinically —for instance, pneumo-encephalograph in the presence of raised intracranial pressure. A second choice of investigation is therefore given.

Results

Since completing Stage 1 of the weighting (the operation by which positive signs are given a weight of 100 against negative signs which have a weight of one), the tests on seven new patients have been processed. Five of these patients were in Group 1; two were in Group 2.

The predicted diagnosis was completely correct in five cases and was either a near miss or partly correct in the other two. These results, though far too few to be of real significance, are very encouraging.

Discussion

It may be valuable to repeat certain generalisations about computer-assisted diagnoses.

1. The computer in no way replaces the observer. Each sign in the list must be thought about and assessed as positive, negative or unreadable, and the definition of all the signs must be clear in the mind of the radiologist. This in itself demands a clarification of thought which should go a long way toward improving interpretation.

2. The choice of signs to put in the program in the first instance is made on the basis of previous experience; but it is possible to supplement or subtract from them. In designing the program, an attempt was made to include everything that the radiologist had found useful in the past, while at the same time leaving out not only what was obviously an alternative way of expressing the same anatomical deformity, but also what seemed indefinable.

The list of basic tests will require additions from time to time. It contains almost all that I have found valuable in diagnosis of cerebral tumours without the help of a computer; but without doubt there are many other signs to be elicited, some of them already of established

value in the hands of other neuroradiologists. It is important, however, to include only that which is reasonably easy to define. Measurements would have been ideal, and yet the use of actual measurements in neuroradiology is disappointing, for the criteria of normality are so wide. The use of a computer does not provide a shortcut. It is only the means towards a more sophisticated appraisal of observations already made.

3. Because information about the margins of an intracranial tumour is so often inadequate, the computer program does not attempt an estimate of size, but does record the fact that the actual margin of the tumour has been determined and by which method of investigation.

4. By its nature, this method cannot recognise the relative incidence of diseases in the general population—at least until a large amount of material has been accumulated and many patients have been investigated.

If the signs in a new case fit two diseases well, though neither perfectly, one of the diseases being rare and one common, the computer will not at present take this factor into account in expressing the diagnostic probability.

In order to manage such patients, the clinician needs to know the answers to two questions. On the basis of signs or symptoms alone: 1) What are the likely diagnoses? 2) What is their probability? Furthermore, he needs to ask: How would the relative incidence of these diseases alter the answers to the preceding questions? Discussion up to now has dealt with the questions of diagnoses and probability. Many more patients must be assessed before the third question can be answered.

Retrospective review of the neuroradiologists' index up to 1964 has given some statistics of groups of diseases falling into the scheme of this study, which, without being detailed enough to provide a full pathological diagnosis, may be of some assistance.

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