

COMPUTER DISCRIMINATION BETWEEN DISEASES OF THE BRAIN BASED ON MR IMAGE FEATURES

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INTRODUCTION

In attempting to achieve a diagnosis both novice and expert radiologists tend to simplify the process by grouping contending diagnosis candidates into “small worlds” of similar appearance or similar clinical features. Comparing a current undiagnosed case with an archive of image feature descriptors of past cases also provides opportunities for discovering the roles of individual image features in discrimination. Techniques of implementing such potentially rewarding analyses require a standard language of descriptors (an image description language or IDL) that can be used consistently on an archive of cases to blindly describe them without knowledge of the final diagnoses. It is important that the radiological protocols employed should be matched between examples and new cases and that there should be sufficient numbers in the archive to provide statistically convincing data.

MATERIAL AND METHODS

Image Description Language (IDL)

Previous work has described the computer based tutorial system that encompasses and teaches the image description language in its comprehensive and in a shortened form [1,2,3]. Figure 1 shows the interface to the system in which a partial description has been entered (bottom left).

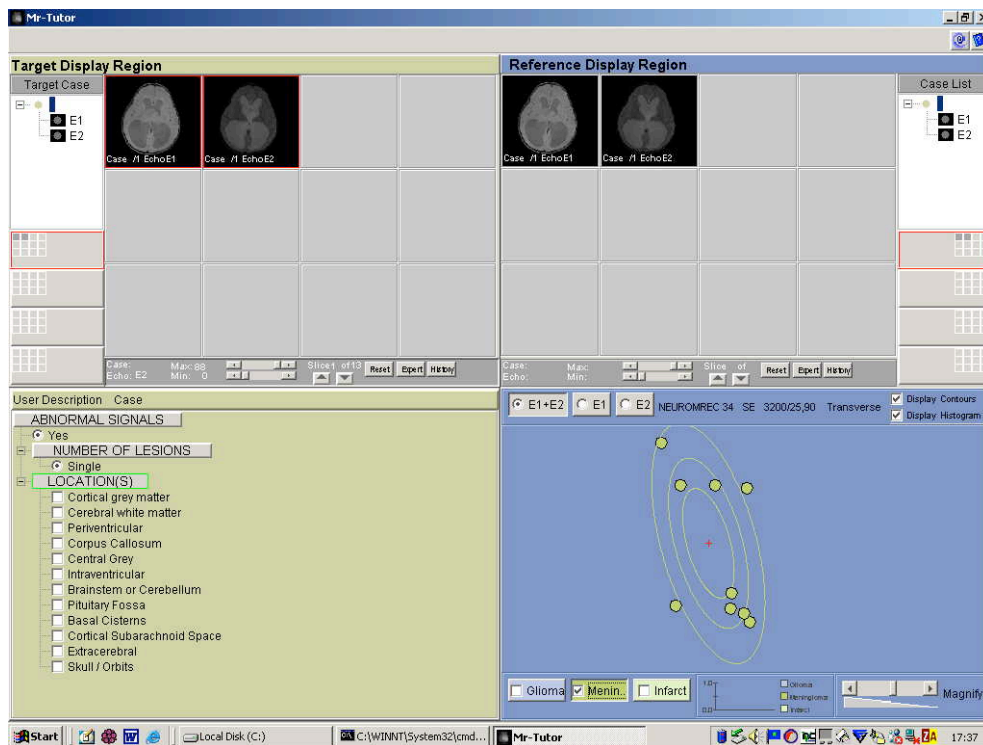


Figure 1: MR Tutor showing meningioma small world

Archive

Some 1200 patients' abnormal MR head and brain images were described blind to clinical findings and age and gender. The archive consists of the detailed, formal, menu-driven descriptions of all these images. The archive also contains the confirmed or working diagnoses, the degree of certainty of those diagnoses and the summaries of the clinical findings and case histories.

Small Worlds

In order to maximise the potential of the work, 18 neuroradiologists from the British Society of Neuroradiologists and 6 from Spain were asked to provide their choice of groups ("small worlds") of confusable diseases that present the greatest difficulties and in which differential diagnostic help might be the most rewarding [4,5]

Image Feature Overview Space

Previous work also outlines the unique "image-overview space"[5]. This displays for every case in the chosen small world a spot in a two dimensional computer window representing a projection, by the statistical technique of Multiple Correspondence Analysis, from a multi-dimensional space calculated from the presence of all its feature descriptors. The feature space inhabited by its constituent cases looks like a star map (see bottom right of Figure 1, which shows meningioma cases only).

These case-based ‘star maps’ are available for single T1 or T2 or proton density single echo or combined double echo sequences. Comparisons between the positions of the archived cases of each disease allow the user to visualise the feature overlap between diseases and the most typical examples of each disease. Clicking on each spot displays the associated case’s MR images.

The archived image descriptions of each case can also be simultaneously displayed on the screen. As the mouse cursor alights on the name of each feature descriptor every case in the overview space that possesses that feature will be highlighted. Thus the user is able not only to form an impression of the likely confusions and differences between the appearances of candidate diseases but to identify which features of the images contribute the greater power of discrimination in the chosen small world.

EXAMPLES OF FINDINGS IN VARIOUS ‘SMALL WORLDS’

1. Small World: Meningioma vs. Glioma .

The archive contained 20 clinically certain and pathologically described and classified gliomas and nine meningiomas. This small world was chosen as worthwhile studying by only one of the neuroradiologists consulted, but as a subset of the problem intra- vs. extra-axial masses it was chosen by 6 out of 24 neuroradiologists.

The image overview space for these two types of tumour showed a lot of overlap, especially between more malignant gliomas and meningiomas, which seemed to contradict the general conclusion of practising neuroradiologists who report being confident in their diagnosis of meningioma. As a result, the authors of the present paper instituted a search for features not in the IDL that might provide clearer discrimination. Two such features were identified. One is described as the “naked tumour” sign in which in T2 weighted scans of meningiomas the edge of the tumour facing away from the cerebrum appears naked, having no visible surrounding capsular structure. The only case having this sign in the whole material that was not a meningioma was a large thrombosed aneurysm.

2. Small World : Meningiomas alone

The 9 meningiomas split clearly into two groups by their appearances, see bottom right of Figure 1. It was clear that although the one group of 5 were all supratentorial and the other 4 infratentorial, it was largely the details of their appearance that separated them.

All the supratentorial meningiomas and/or their surrounding oedema but none of the infratentorial ones involved the cerebral white matter. The margins of infratentorial meningiomas were all sharp; of supratentorial meningiomas none had sharp margins.

At their largest, infratentorial meningiomas were never more than 10cm² in area. 4/5 supratentorial meningiomas were larger than 20cm².

3. *Small World : Gliomas alone*

The material contained 20 gliomas confirmed by operation or autopsy but in only 15 was the pathological description of the tumour in the case notes adequate and the glioma categorised as a recognised type. Also, because of the period during which the cases were collected, some now obsolescent terminology (e.g. Kernohan classification of gliomas) was employed.

Many of the localisation descriptors were shared by most glioma types and therefore of little discriminatory power. On the other hand radiological signs concerning internal focal structures and particularly the intensities of the tumour material gave strong discriminatory evidence of their morphological type. The diagnosis of oligodendrogliomas and of low grade gliomas were particularly strongly supported, see Table 1.

Table 1. Glioma classification was current at the time of operation and imaging. Internal structures of the tumour images together with their intensities point to their identities. In the lowest row the intensity levels found in each case are separated by commas where: + ++ +++ are graduated degrees of hyperintensity, = is isointense with white matter, and - -- --- are graduated hypointensities.

| CHARACTERISTICS OF GLIOMAS | | | | | | |
|----------------------------|------------------------------------|-------------------------------------------------------------|-------------------------------------------------------------|--------------------------------|----------------------------------------------------|-------------------------------------------------|
| | Glioblastoma (2 cases) | Astrocytoma grades 3 & 4 & malignant glioma (4 cases) | | Oligodendroglioma (4 cases) | | Low grade glioma (5 cases) |
| Location | Cerebrum | Brainstem (1 case) | Cerebrum (3 cases) | Brain-stem (1 case) | Cerebrum (3 cases) | Cerebrum |
| Shape | Irregular | | | | Irregular/ irregular rounded | |
| Internal structure | Heterogeneous or homogeneous | | All contain focal structure which is structured | | All contain focal structure, 2 structured | 2 contain focal structures, 4 homogeneous |
| Intensities | + or ++ | | + =, ++ = -, +++ ++ + = | | --, ---, ++ + -- --- | +++,+++, +++,+++, +++ - |

1. *Small World : Infarcts vs. Multiple Sclerosis*

Table 2: Factors helping to distinguish infarcts from M.S.

| | INFARCTS | M.S. | |
|----------------------------------------------------------------------------------------------------------------|----------|-------|-----------------------------------------------------------|
| Lesions whose shape is “Rounded or Irregularly Rounded” | 1/8 | 20/31 | Significance P =0.015 Fisher’s Exact (2-tailed) |
| Proportion of cases with “A single lesion” | 5/8 | 4/31 | significance P =0.009 Fisher’s Exact (2-tailed) |
| In the image overview space, cases with a single lesion projected in the overlap area of MS with Infarct space | 4/5 | 0/4 | |

Note that approximately 1/5 of MS cases are projected into Infarct Space, and that

- Of cases with a single MS lesion (4 cases) 0 lay in Infarct Space
- Of cases with 2-10 MS lesions per case (10 cases) 2 lay in Infarct Space
- Of cases with more than 10 MS lesions per case (17 cases) 4 lay in Infarct Space

5. *Small World : Infarcts vs. Gliomas*

Table 3: Factors helping to distinguish infarcts from gliomas.

| | INFARCTS | GLIOMAS | |
|-----------------------------------------------------|----------|---------|----------------------------------------------|
| Lesions containing A “Focal Structure” | 0/8 | 11/20 | P =0.01 Fisher’s Exact (2-tailed) |
| Lesions classified “Unstructured And Heterogeneous” | 7/8 | 8/20 | P =0.038 Fisher’s Exact (2-tailed) |

DISCUSSION

In the present work using magnetic resonance imaging in neuroradiology the need for a large archive is probably the most demanding, bearing in mind the wide range of diagnoses encountered in MR practice for disease of the head and brain. 1200 is not very many.

Nevertheless our experience has provided some results that raise our hopes that these demanding activities can be worthwhile for diagnostic aid for a new case, for differential diagnosis in general, for training in observation and for contributing enlightenment about the natural history of disease processes.

The good correlation of image descriptions to glioma morphology carries over satisfactorily into the more recent WHO classification[6]. Image appearances correctly and strongly point to “Low Grade Gliomas” and to “Oligodendrogliomas” in the characteristics of which the old and new WHO classifications agree. MRI distinction between glioma types is hesitatingly approached by most neuroradiologists.

These observations give some indications of how the confusability between diagnoses in a small world can be assessed. Eyeballing the small world displays in the image overview window provides an impression of the strength of separability between the constituent diseases of the small world under investigation. Case by case and descriptor by descriptor analysis is a data-mining exercise that may contribute quantifiable information applicable to precisely identified diagnostic problems.

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