ORIGINAL ARTICLES

Magnetic resonance imaging in neurological disorders

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Abstract

To investigate the role of magnetic resonance imaging (MRI) in neurological disorders, 115 children were studied in two groups. Group A (78 patients) was studied by paired computed tomography and MRI cranial scans. Group B (37 patients) was studied by paired computed tomography assisted myelography (CTM) and MRI spinal scans. In group A, the scans were generally equivalent for supratentorial tumours and for investigating fits, hydrocephalus, benign intracranial hypertension, and cerebral atrophies, but MRI scanning was superior for posterior fossa tumours and cysts. In group B, MRI scans were superior for intramedullary spinal tumours, spinal dysraphic problems with tethering or syrinx, and were complementary to CTM in diastematomyelia.

The advent of magnetic resonance imaging (MRI) has provided a further powerful tool for the investigation of diseases of the central nervous system. Current limited availability of scanning time and of health service resources, however, makes the prudent selection of patients for its use imperative.

Consequently, this study was devised to compare the usefulness of MRI cranial and spinal scans with cranial computed tomography and computed tomography assisted myelography (CTM). The study aims were to look at the role of MRI in childhood neurological disorders, to compare the accuracy of diagnosis with computed tomograms, and to identify the pathological entities where specific scanning modalities are preferable, and others where the modalities are equivalent or complementary. Thus the study hoped to identify the most appropriate initial investigation in certain clinical situations.

Subjects and methods

One hundred and fifteen children (60 girls and 55 boys) aged 2 days-17 years (mean 9.2 years) were studied. In group A, 78 children were studied with paired computed tomograms and MRI cranial scans. The scans were performed on the same day in most children, and all within two weeks of each other. In group B, 37 children were studied with paired CTM and MRI spinal scans. The imaging units used were the Picker 1200SX for computed tomography and a Picker 0.15 Tesla Resistive System for MRI scanning.

The scans in both groups were reported by the same neuroradiologist who was given the clinical details. The radiological diagnosis was

then compared with the final clinical diagnosis. The scans were then graded for diagnostic value according to the following classification: grade 1—both scans were negative (normal); grade 2—both scans were positive and equivalent; grade 3—the MRI scan was superior to the computed tomogram; grade 4—the computed tomogram was superior to the MRI scan.

Informed parental consent was obtained before both computed tomography and MRI scanning.

Results

The results from comparing the radiological

Figure 1 An 8 year old girl. (a) Computed tomogram showing tumour extension into the left geniculate region (curved arrow) of histologically proved optic chiasm glioma. (b) T2 weighted (TR=2000 msec, TE=80 msec) sagittal MRI scan demonstrating a large suprasellar high signal mass. As axial images were not obtained the posterior extension was not appreciated.

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Table 1 Results of group A: computed tomography and MRI cranial scans

Pathology	Both scans negative (grade 1)	Both scans positive (grade 2)	MRI superior (grade 3)	Computed tomography superior (grade 4)	Total
(1) Tumours:					
(a) Supratentorial	—	16	4	1	21
(b) Infratentorial	1	5	8	—	14
(2) Cysts	—	2	3	—	5
(3) Hydrocephalus or benign intracranial hypertension	1	8	—	—	9
(4) Atrophic states	—	3	—	—	3
(5) Degenerative states	—	3	2	—	5
(6) Fits	8	3	—	—	11
(7) Miscellaneous neurological disorders	7	1	2	—	10
Total	17	41	19	1	78

Figure 2 A 12 year old girl. (a) Axial computed tomogram through the posterior fossa. An intrinsic lesion is inferred by the presence of tissue bulging into the right side of the fourth ventricle (arrows); however, tumour definition is poor. (b) Axial and (c) sagittal T2 weighted (TR=2000 msec, TE=80 msec). (d) Coronal T1 weighted inversion recovery (TR=1660 msec, T1=400 msec) section clearly defines the lesion (arrows) and localises it within the brainstem and involves the right middle cerebellar peduncle (histology: brainstem glioma).

diagnosis and the final clinical diagnosis made on discharge for the two groups are shown in tables 1 and 2.

GROUP A (TABLE 1)

(1a) Tumours—supratentorial

There were 21 children with suspected supratentorial tumours. The scans in 16 (76%) cases

were judged to be equivalent, whereas in four (19%) patients the MRI was superior in defining the anatomy and extent of the tumour. These four tumours included single cases of pilocytic astrocytoma, choroid plexus carcinoma, optic chiasm glioma, and mid brain glioma. The single case where the computed tomogram was adjudged to be superior had an optic chiasm pilocytic astrocytoma. The computed tomo-

Figure 3 A 7 year old boy. (a) Axial computed tomography section. Appreciable atrophy is present but no definite parenchymal lesion is seen. (b) Axial T2 weighted (TR=2000 msec, TE=80 msec) section shows multiple foci of high signal in the subcortical white matter of both cerebral hemispheres.

Table 2 Results of group B: paired CTM and MRI spinal scans

Pathology	Both scans negative (grade 1)	Both scans positive (grade 2)	MRI superior (grade 3)	CTM superior (grade 4)	Total
(1) Spina bifida aperta/cystica	—	6	10	—	16
(2) Diastematomyelia	—	3	—	—	3
(3) Tight filum terminale syndrome (±syrinx)	—	1	3	1	5
(4) Spinal tumours (±syrinx)	—	2	3	1	6
(5) Miscellaneous spinal disorders	3	1	3	—	7
Total	3	13	19	2	37

gram showed posterior extension of the tumour along the optic tract. This extension was not well visualised on MRI, which had given the erroneous diagnosis of a hypothalamic glioma (fig 1). The appropriate use of axial magnetic resonance images, however, would probably have demonstrated clearly the full extent of the lesion along the specific pathways.

(1b) Tumours—infratentorial

The 14 children with suspected infratentorial tumours included a boy with symptoms of headache, ataxia, and nystagmus in whom both scans were negative and his symptoms subsequently resolved. In the remaining 13 children the studies were judged to be equivalent in five (39%) (three medulloblastomas, one brain stem

Figure 4 A 13 year old girl. (a) Immediate postmyelographic axial computed tomogram through L5. Neural (short curved arrow) and lipomatous (long curved arrow) tissue is seen to pass posteriorly into a meningocele (straight arrow). Nerve roots can be seen arising from the anterior surface of the low cord. (b) T1 weighted (TR=500 msec, TE=40 msec) sagittal scan. The relationship of the higher signal lipomatous tissue (short curved arrows) can be clearly seen, lying on the dorsal surface of the cord (long curved arrow), both passing posteriorly into the bilobed meningocele.

Figure 5 A 3 year old girl. (a) Anterior-posterior view from myelogram showing the classical appearances of a double arachnoid-dural sac diastematomyelia with an interposed bone spur (arrow). The cord above the split appears a little bulky. (b) Postmyelographic computed tomogram through the cord at the T12 level shows no obvious abnormality. Delayed scanning was not performed. (c) T1 weighted (TR=500 msec, TE=40 msec) sagittal scan demonstrates a septated syringohydromyelic cavity in the cord above the cleft (curved arrow). The fibro-osseous spur (straight white arrow) is seen. An unsuspected filar lipoma (straight black arrow) is noted.

glioma, one juvenile astrocytoma) and the MRI was superior in eight (62%) (three cerebellar astrocytomas (fig 2), two medullary astrocytomas, and single cases of medulloblastoma, brain stem glioma, and a tectal plate glioma). In all cases where a tumour was present, however, an abnormality was picked up by both imaging modalities.

(2) Cysts

Five patients had cystic lesions, of which four

were arachnoid cysts. In three the MRI scan was judged to be superior, defining the complicated anatomical connections particularly when the posterior fossa was involved.

(3) Hydrocephalus or benign intracranial hypertension

Nine children had suspected hydrocephalus or benign intracranial hypertension. In the one patient with benign intracranial hypertension both scans were normal. In the remaining eight cases with hydrocephalus abnormalities were detected equally well by both techniques.

(4) Atrophic states

Three children had atrophic states clearly demonstrated by either scan.

(5) Degenerative states

Five children were investigated for suspected degenerative disorders, of whom in one case each of Krabbe's leucodystrophy, Wilson's disease, and optic neuritis the scans were equivalent. However, in two children the MRI was superior demonstrating pathology not seen on the computed tomogram. One had Leigh's disease with a left medullary lesion demonstrated, and the other had florid changes of demyelination (fig 3) not seen on the computed tomogram.

(6) Fits

Eleven children were investigated for troublesome focal fits whose electroencephalograms had suggested an underlying structural abnormality. In eight both scans were normal. In the remaining three both scans identified the abnormalities including one with tuberous sclerosis, one with cerebral atrophy, and one with congenital hamartoma.

(7) Miscellaneous neurological disorders

Ten children had a variety of suspected or known neurological disorders. In seven both scans were negative. One child had a lentiform nucleus infarct clearly seen on both scans. The MRI was superior in two, identifying a cavum septum pellucidum in one, and haematomas secondary to vasculitis in the other.

For the whole of group A (table 1) 58 out of 78 (74%) scans were equivalent (either positive or normal). In one child the computed tomogram was superior, and in 19 (24%) the MRI was superior, particularly with posterior fossa tumours and cysts and certain degenerative disorders.

GROUP B (TABLE 2)

(1) Spina bifida aperta/cystica

Sixteen patients were investigated after the development of new neurological signs suggesting cord tethering or cavitation. In six the scans were judged to be equal, but in 10 the MRI was superior particularly in subjects with lipomyelomeningoceles in the lumbosacral region (fig 4).

Figure 6 A 12 year old boy. (a) Postmyelographic computed tomogram shows an apparently normal distal thoracic cord. Delayed scanning was not performed. (b) T1 weighted (TR=500 msec, TE=40 msec) scan shows a linear central syringohydromyelic cavity (arrow) in a low lying cord. The thickened tethering filum terminale was better demonstrated by computed tomography.

(2) Diastematomyelia

Three patients had diastematomyelias which were equally well demonstrated by both imaging techniques. While CTM more clearly defined the finer neural detail and fibro-osseous septum, if present, between the two hemicords, MRI provided additional information as to the presence of associated cord cavitation (seen in two of the cases) (fig 5).

(3) Tight filum terminale syndrome

Five children had a tight filum terminale

syndrome. In one the scans were of equivalent value. In three the MRI scan was superior, demonstrating an associated syrinx in two (fig 6), and in the other with kyphoscoliosis showing cord thinning. A single child with arthrogryposis and scoliosis had cord tethering which was more clearly defined by CTM.

(4) Spinal tumours

Six children had spinal tumours; in three the MRI was the superior examination (fig 7) whereas in two the studies were equal. A single

Figure 7 A 2 year old girl. (a) Postmyelographic computed tomogram. There is diffuse expansion of the cord at T12, but lesion definition and tissue characterisation is poor. (b) T1 weighted (TR=500 msec, TE=40 msec) sagittal section demonstrates a well circumscribed cystic structure felt to represent an intramedullary dermoid, confirmed at surgery.

Figure 8 A 3 year old girl. (a) Postmyelogram computed tomogram shows a small amount of extradural soft tissue (arrows) indenting the anterior theca. Subtle end plate changes can be seen in the posterior aspect of the vertebral body. (b) Sagittal STIR (TR=1100 msec, TI=100 sec). Florid high signal is seen in the bodies of L2 and L3 adjacent to the abnormal interposed disc which shows signal reduction and loss of height, features characteristic of discitis.

girl had intrathecal droplet metastases seen on CTM that could not be demonstrated with certainty by MRI.

(5) Miscellaneous spinal disorders

Three children with bladder dysfunction or long tract signs, or both, had normal scans. The scans were equally informative in one child with mesodermal dysplasia. The MRI was superior in three children, including one with cervical cord trauma from a knife stab wound, one after previous scoliosis surgery with an associated lipoma, and a girl with discitis (fig 8).

Thus in group B (table 2) the imaging techniques were equivalent in 16 out of 37

(43%) (either positive or negative), the MRI was superior in 19 (51%) and CTM was better in two (5%).

Discussion

In certain fortunate centres the availability of a full range of imaging methods enables possible neurological problems to be investigated in various alternative ways. In many district and referral hospitals, however, MRI scanning, and even computed tomography, may not be freely available. Given the current concerns about scarce health resources it is important that children are investigated by the most appropriate method. We have attempted to suggest possible guidelines for the use of MRI scanning.

The performance of both scans has possible advantages in yielding greater certainty of diagnosis and providing complementary information. Greater expertise in the scanning techniques may also result. In addition even though an additional scan may not alter the diagnosis it may well aid the neurosurgeon in planning operative intervention such as the case shown in fig 9, where the computed tomogram showed a large enhancing mass based on the left thalamus, considered to be inoperable by the neurosurgeon. The magnetic resonance scan, however, showed a well circumscribed lesion adjacent to the skull base, which was felt to be accessible by a subtemporal approach. This was successfully done leaving the child with minor disability only.

The coronal plane most nearly approximates to the operative field in posterior fossa tumours and the siting and extent of the necessary craniotomy can best be assessed from such sections. Posterior and inferior extension of tumour into the vallecula, cisterna magna, and upper cervical canal; lateral extension into the cerebellar peduncles and cerebellopontine cisterns and superior extension through the tentorial hiatus can be readily assessed from the coronal perspective.

The indiscriminate use of both scanning methods would, however, be wasteful of often limited resources with an average cost in our unit for an enhanced computed tomogram of £155 and for an MRI cranial scan of £206. Average costs of CTM are £312, and for an MRI spinal study £206. Performing both scans can place an extra burden upon the patient and family, as well as necessitating longer hospitalisation and potentially straining the family's resources to cover the hospital stay.

Although the numbers were not large, this study showed that MRI and computed tomography cranial scans gave identical information when investigating the possibility of a structural lesion in a child with epilepsy. Previous reports have suggested the superiority of MRI scanning in this clinical situation.^{1 2} Our advice would be to do computed tomography, and if the scan is negative consider requesting an MRI scan only if seizures are difficult to control despite optimal anticonvulsant treatment.

Similarly, in most children with hydrocephalus, benign intracranial hypertension, or cerebral atrophies either scanning method

Figure 9 A 7 year old girl. (a) Enhanced axial computed tomogram demonstrating a rather poorly defined strongly enhancing lesion in the deep left temporal region, extending to the left cerebral peduncle. (b) Coronal and (c) sagittal T1 weighted (SE 500 msec, TE=40 msec) sections show a clearly defined low signal lesion (arrows). On the basis of the coronal scan the neurosurgeon felt that a subtemporal approach was feasible and a macroscopic resection obtained. (d) Six months postsurgical T1 weighted section. No tumour residuum demonstrated (pathology: juvenile pilocytic astrocytoma).

(according to the ease of availability) could be expected to yield the same information.

Posterior fossa tumours and cysts are usually best investigated by MRI.³⁻⁵ Suspected supratentorial lesions can be investigated initially by either method, although it appears that in most cases the MRI scan will be at least as good as the computed tomogram.

In children with complicated spinal dysraphic abnormalities, particularly those with associated lipomas, the MRI scans tend to be more informative.⁶ Similarly in children with intramedullary spinal tumours the MRI scans yield greater information. However, subtle metastatic deposits may be more clearly seen on CTM.

In the investigation of children with diastematomyelia the two methods tend to be complementary. However, MRI is consistently superior for the demonstration of unsuspected or occult cord cavitation.

It is especially in the sphere of dysraphic lesions and assessment of childhood kyphoscoliotic states that close liaison between the referring clinician and neuroradiologist is essential to optimise the diagnostic information from magnetic resonance scanning. The choice of correct imaging parameters may considerably enhance the accuracy of the examination. In particular the appropriate use of pulse sequences will reduce the risk of failing to identify subtle intraspinal lesions and enable more precise tissue characterisation.

In children with degenerative disorders such as multiple sclerosis,^{7,8} and for studying myelination disorders and patterns in infancy, MRI scanning provides clearer and more accurate information.^{9,10}

This study has been based upon the comparison between computed tomography and a low field (0.15 Tesla (T)) MRI system. It is accepted

that imaging employing mid or high field systems considerably improves the diagnostic accuracy and resolution capabilities of this modality. The field homogeneity at 0.15T is suboptimal and the inability to obtain cardio-respiratory gating produced relatively poor quality imaging in the spine. The wider use of higher field systems will lead to improved spinal imaging especially when coupled with fast sequences and improved surface coils. An advantage of a low field system has been the ability to perform general anaesthetics with minimal modification of the equipment. Most patients scanned in our study, however, were given oral sedation only. Where possible selection of the shorter T1 weighted spin echo sequences enabled a reduction in the overall scan time.

Since this study the introduction of gadolinium diethylene triamine pentacetic acid (DTPA) has considerably improved the imaging capabilities of MRI with the ability to define intrinsic and extrinsic central nervous system pathology with greater sensitivity. It is foreseen that this will lead to the more frequent use of MRI scanning in the neuraxis.

In conclusion, where MRI imaging is not freely available, we would recommend that it is best reserved for children with a suspected posterior fossa tumour or cyst, for complicated

spinal abnormalities, and for certain suspected degenerative disorders. Furthermore, MRI enables the use of potential frequent or serial scanning without the attendant risks of a heavy radiation burden to this young group of patients.

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