Original article:

Role of Diffusion weighted imaging in evaluation of intracranial pathologies

Dr. Ravinder Kumar[1] , Dr. Jyoti kundu [2]

[1](MD (Radiodiagnosis) , Assistant Professor, Dept. of Radiology, Geetanjali Medical College & Hospital/ Geetanjali University , India

[2](MDS (Prosthodontics) , Senior Lecturer, Dept. of Prosthodontics, Geetanjali Dental College & Hospital/ Geetanjali University , India

Corresponding author : Dr. Ravinder Kumar

Date of submission: 04 November 2014; Date of Publication: 10 December 2014

Abstract:

Objective: This study aims to assess the role & efficacy of Diffusion-weighted imaging in evaluation of intracranial pathologies.

Material & Methods: Total 80 cases of various intracranial pathologies of all age groups and either sex were evaluated. All MR images were obtained with a 1.5-T superconducting system (SIEMENS HEALTHCARE SYSTEMS) using a circularly polarized head coil.

Results: Out of 80 cases, 2 cases showed no findings on MR (conventional and diffusion MR), and a total of 125 lesions was found in 78 cases. Infarct (68%) was the commonest lesion seen in our study. Of these, Acute infarcts which presented within 24 hours of onset of ictus represented 70%, Hyperacute infarcts (9.41%) ,Subacute infarcts (10.5%) and Chronic infarcts (9.41%) were less common. In cases of acute infarcts of the total 60 lesions, Conventional MR (T2WI) and FLAIR could detect 96.6 % of the lesions and diffusion MR had 100% detection rate for acute infarcts.Diffusion MR, conventional MR and FLAIR had equal (100%) detection rate for subacute Infarcts. Both conventional and diffusion MR(100%) had equal detection rate for chronic infarcts. Among the non-infarct lesions, Meningioma was most common with 10 lesions (8%) detected on DW MR. Least common lesions detected by DW MR included Medulloblastoma & Subdural Empyema -1 Lesion(0.8%) each.

Conclusion: DWI is more sensitive & diagnostic in cases of infarct when comparatively evaluated with conventional MR & FLAIR .

Keywords: Conventional MR, Difffusion Weighted Imaging

Introduction

Intracranial lesions are the most important cause of neurological signs and symptoms, in which stroke is the most common cause of mortality and morbidity.With the advent of many advanced imaging modalities, radiology is placing a pivotal role in the early diagnosis and hence further management of disease. The various modalities being ultrasound, computed tomography, single photon emission computed snew physiological imaging capabilities offers new opportunities for early detection and delineation of most neurological pathologies at an early stage.

Diffusion weighted MR imaging is a new technique which measures the microscopic motion of water protons and hence provides unique information on the

physiological state of tissues. It provides image contrast that is dependent on the molecular motion of water, which may **be** substantially altered by disease**.** So, this study aims to assess the role & efficacy of Diffusion-weighted imaging in evaluation of intracranial pathologies, differentiating early infarct from chronic infarct & evaluating rim-Enhancing Brain Masses.

Materials & methods

Eighty patients suffering from various intracranial pathologies of all age groups and either sex were included in the study .

All MR images were obtained with a 1.5-T superconducting system using a circularly polarized head coil. Sagittal T1-weighted (T1WI) localizing images (TR/TE/NEX, 15/6/1) were acquired first, and then unenhanced axial T2-weighted (T1WI) and T2-weighted (T2WI) images were obtained in each patient**).** DWI images and conventional MRI images were obtained in all patients. All conventional sequences were obtained with a 5-mm section thickness and a 1-mm intersection gap. DWI was performed in the transverse plane by using a spin-echo echoplanar imaging sequence with the following parameters **(Table1).**

Apparent diffusion coefficient (ADC) values were calculated on die basis of the following equation:

- $In\ S(G) - In\ S(0) - 2\left[\gamma\Delta^2 x\ G^2 x\ \delta^2\ x\ \left(\Delta - \frac{\delta}{3}\right)\right] x\ (ADC)$
- where G is the amplitude of the pulsed diffusion gradient, $\gamma$is the gyromagnetic ratio, Δis the interval between the diffusion gradients, $\delta$is the duration of diffusion gradients, S(G) is the signal strength with pulsed diffusion gradient on, S(0) is the signal strength with the pulsed diffusion gradient off.

MR scan was examined for:

(a) Morphological changes
   I. Gyral Swelling
   II. Sulcal Effacement.

(b) Signal intensity alteration in Tl, T2 and FLAIR images

(c) Altered signal intensity areas in DW Images

Results

Out of 80 cases, 2 cases showed no findings on MR (conventional and diffusion MR), and a total of 125 lesions was found in 78 cases. **(TableII).**

Infarct (68%) was the commonest lesion seen in our study. Of these, Acute infarcts which presented within 24 hours of onset of ictus represented 70%, Hyperacute infarcts (9.41%) ,Subacute infarcts (10.5%) and Chronic infarcts (9.41%) were less common. **(TableIII).**

The commonest presenting symptom in patients with cerebral infarction was hemiparesis (56.2%), right being slightly more common (31.2%) than left (25%). **(TableIV).**

- Headache was seen in 22.5% cases.
- Facial nerve palsy was seen in 15% of cases.
- Cerebellar symptoms were noted in 18.75% of cases.
- Monoparesis was found in 8.7% of cases.
- Fever & disorientation was found in 8.75% cases

Conventional MR features of cerebral infarction shows T1 WI was positive in 37 out of 50 (74%) cases.The commonest alteration of signal intensity in T1 WI was hypointensity seen in 78% of cases.T2 WI was positive in 45 (90%) cases. The most common alternation of signal intensity of T2 WI was found to be hyperintensity (90%). **(Table V).**

FLAIR features of cerebral infarction (Table VI) shows

i. FLAIR was positive in 46 (92%) cases.

www.ijbamr.com P ISSN: 2250-284X , E ISSN : 2250-2858

ii FLAIR was normal in 2 (4%) cases.

ii. The most common alternation of signal intensity noted in FLAIR was hyperintensity seen in (88%) of lesions.

i. 4% of cases showed hypointensity with peripheral hyperintensity suggestive of chronic infarcts.

Diffusion MR imaging features of cerebral infarction(Table VII) shows

- DWl was positive in 46 (92%) cases.
- DWI was found to be norma! in only 2 (4%) cases.
- 78% of cases showed increasing hyperintensity from bO to b1OOO suggestive of acute infarcts.
- Isotensity on b0 to b1000 were noted in 8% of cases.
- 6% cases showed decreasing hyperintensity from b0 to bl000 suggestive of chronic infarcts.

Distribution of ischaemic lesions according to arterial territories (TableVIII) shows

67.3% of MCA infarcts were in acute stage**.(fig.I & fig. II)**

MCA was the most common arterial territory involved in all stages of infarct.

PCA was the most common arterial territory to be involved next to MCA Comparative analysis of conventional MR, FLAIR, and diffusion MR in the detection of cerebral infarction **(Table IX)** shows Conventional MR detected 45 true positive cases and was false negative in 3 cases with sensitivity of 93.75%.FLAIR was found to be sensitive in (95.8%)which is more sensitive than conventional MR and Diffusion MR was true positive in all cases with an over all sensitivity of 100% for all stages of cerebral infarction.

2 cases were normal on conventional,FLAIR and diffusion which were later on proved to be Transient ischaemic attacks (TIA).

- In cases of acute infarcts of the total 60 lesions, Conventional MR (T2WI) and FLAIR could detect 96.6 % of the lesions and diffusion MR had 100% detection rate for acute infarcts.
- Diffusion MR, conventional MR and FLAIR had equal (100%) detection rate for subacute Infarcts. Both conventional and diffusion MR(100%) had equal detection rate for chronic infarcts**.**
- Among the non-infarct lesions, Meningioma was most common with 10 lesions (8%) detected on DW MR. Least common lesions detected by DW MR included Medulloblastoma & Subdural Empyema -1 Lesion(0.8%) each**.(FIG.III**

Discussion

The present study was undertaken to evaluate the role of diffusion weighted echoplanar imaging in the evaluation of various intracranial pathology.

The commonest presenting symptom was hemiparesis in 45(56.2%) patients, right sided being slightly more common (31.2%) than the left (25%). Monoparesis was seen in 7(8.7%) patients, facial nerve palsy in 12(15%) patients and cerebellar symptoms were noted in 15(18.75%) patients.

Hyperacute infarcts

A total of 5(10%) cases seen within the 6 hours period and 8(9.41%) lesions were found in 5 of these cases. 7(87.5%) hyperacute lesions were detected in the MCA territory and only 1 hyperacute lesion was seen in the watershed region. This high incidence of hyperacute infarcts in MCA territory may be because thrombosis or embolism of middle **Conventional MR T1WI** imaging was positive in only 2(40%) cases of hyperacute

www.ijbamr.com P ISSN: 2250-284X , E ISSN : 2250-2858

infarcts. Both the cases showed iso to hypo intensity of the infarcted urea. This hypointensity can be explained by the prolongation of infarcted region produced due to increased water content in the region of infarct. Vira pongs et al also reported a similar lower sensitivity of T1WI.

Conventional MR T_2WI was positive in 4 patients of hyperacute infarcts and a total of 6(75%) lesions were detected. The commonest alternation of signal intensity found was hyperintensity, which was seen in all 4 cases detected by T2WI, which can be explained by prolongation of T2 values due to increased water content in the region of infarct. **Yuh et al, Bryan et al** also found a similar sensitivity for lesion detection by T2WI within 6 hours.

FLAIR was diagnostic in 4 cases and detected 7(87.5%) of the 8 hyperacute lesions. Hyperintensity was seen in all hyperacute infarcts detected by FLAIR. Thus FLAIR has got a better detection rate than conventional T**2**W images. **Decoene et al** also observed a similar sensitivity for FLAIR over T**2**WI.

Diffusion MR was diagnostic in all 5 cases and detected all the 8 hyperacute lesions. The lesions were seen as increasing regions of hyperintensity with increase in b valves from 0 to 1000. This can be explained due to fact that with increase in b value, ADC decreases and more restricted diffusion of the regions of infarct occurs. Hence it was visualized as increase in hyperintensity of the lesion. Diffusion MR rate and sensitivity over conventional MR and FLAIR. **Warach et al, Gonzaler et al, all found** a similar sensitivity for DWI in hyperacute lesions**.(FIG. IV,V,VI)**

Acute infarcts

- In the present study, acute infarcts represented the highest number of cases 36(72%) with a total number of 60(70.5%) lesions detected. Of acute infarcts, those which presented within 24 hours made upto 44 (51.7%) lesions.
- The most common arterial territory involved in acute infarcts was MCA territory in 31(51.6%) lesions.
- **T1WI** was diagnostic in 28 of 36 (64%) cases. 6(16.6%) cases were found to be falsely negative on TjWI as they showed acute infarcts on diffusion MR. 2 cases were true negative which represented TIA. T1WI showed iso to hypo intensity of the infarcted areas in all 28(64%) cases detected by T1WI.
- **T2WI** was positive in 32(94.4%) cases and a total of 58(96.6%) lesions were detected. The 2 cases of TIA were also normal on T**2**WI (true negatives) The commonest alternation of signal intensity seen on T**2**WI **was** hyperintensity, due to prolonged T**2** values of the infarcted region. **Yuh et al** reported similar findings in their study.
- **FLAIR** was diagnostic in 35 (97.2%) cases. The commonest alteration of signal intensity was hyperintensity seen in 100% of cases detected by FLAIR. FLAIR was again normal in the 2 case, which were proved to be TIA.
- On **DWI** all 36 cases showed areas of altered signal intensity, which showed increasing signal intensity with increase in b values from b0 to bl000 with corresponding loss of signal on ADC maps. A total of 60 lesions were found on DW MR imaging. 2(4%) cases showed negative DWI, which were clinically proven to be TIA. Thus DWI did not show any altered signal intensity areas in TIA. **Alberts et al, Salgado et al, and Marks et al** also reported similar findings in their studies.

www.ijbamr.com P ISSN: 2250-284X , E ISSN : 2250-2858

Subacute infarcts

- Subacute infarcts comprised 4 of 50(8%) cases and the total number of lesions was 9(10.5%).
- The most common arterial territory involved in subacute infarcts was MCA territory in 4(44,4%) lesions.
- T1WI was diagnostic in all 4(100%)cases. The commonest appearance noted in T1WI was hypointensity in 3(75%) cases. As earlier stated this may be due to prolongation of T1 values in the infarcted region. One case showed hyperintensity in the region of infarct in the subacute stage. This can be explained due to bleed in the region of infarct may be due to diapedesis through a leaking endothelium in the subacute infarcts.
- **T2WI** was positive in all **4(100%)** cases, showing hyperintensity in all of them.
- **FLAIR** showed similar detection rate as T**2**WI and the commonest appearance of signal intensity was hyperintensity seen in all cases. The hyperintensity seen can be explained due to earlier subacute stage of infarct which does not get suppressed by FLAIR.
- **DWI** was diagnostic in all 4(100%) cases of subacute infarcts. The infarcts were seen as hyperintense lesions which showed no significant increase or decrease in signal intensity with increase in b value from b0 to bl000. This is due to pseudo-normalization of ADC after 10-14 days of cerebral infarction leading to loss of bright signal intensity in diffusion bl000 with no corresponding signal loss on ADC maps. **Warach et al and Marks et al** observed similar findings respectively**.(fig.VII)**

Chronic infarcts

- **Chronic** infarcts represented 3 to 50 (6%) cases with a total of 8(9.4%) **lesions** detected.
- **MCA was the** most common arterial territory to be involved in chronic **Infarcts 4(50%). PCA** was the next most common 2(25%) to be involved. **Wiener et al et observed** similar arterial territory involvement in their study. T1WI was diagnostic in all 5 cases showing marked hypointcnsity due to more prolonged T1 values of the infarcted region.
- **FLAIR** was also diagnostic in all 3 cases. An appearance of central **&** hypo intensity with peripheral hyperintensity which may represent central cystic encephalomalacia with peripheral gliosis was seen in 2(66.6%) cases. 1 (33.3%) cases were seen as hyperintense lesion on FLAIR which may be due to early chronicity which has not got suppressed by FLAIR.
- **DWI** was also positive in all cases. DW imaging showed hyperintense lesions which decreased with increase in b value from 0 to 1000 and thus all chronic cases were able to be differentiated from acute infarcts. This may be explained due to the vasogenic edema in which there is increased diffusion coefficient in contrast to the decreased coefficient seen in cytotoxic edema of acute infarcts**. Lutsep et al and Schlavg et al** also found similar changes in their study. Thus diffusion imaging was able to differentiate acute from chronic infarcts.

Comparative evaluation of conventional mr, flair and dffusion mr in cases of infarct:

Of the 50 cases of infarct included in our study, infarcts were detected in 48 cases. 2 cases showed no abnormal findings on CT and MR. These cases on follow up showed clinical resolution in 24 hours and thus were diagnosed as TIA.

T1WI was diagnostic in 37(74%) cases and.67(78.8%)lesions. T1 was false negative in

www.ijbamr.com P ISSN: 2250-284X , E ISSN : 2250-2858

11(22%) with an overall sensitivity of 77.08%.

T_2WI was diagnostic in 45(90%) cases, detecting 81(95.2%) lesions. Overall sensitivity for T2 93.7%.

FLAIR was **diagnostic** in **46(92%)** cases and showed **83** (97.6%) lesions, with an overall sensitivity of 95.8%.

DW1 was positive in 48 of 50 cases. It was found to be true negative in 2 cases (TIA) & thus had 100%sensitivity for detection of infarcts. **Marks et al a**lso reported that DW1 was negative in casesbof TIAS in their study.

Of the 8 hyperacute lesion conventional MR T2W detected 6 (75%) lesions, flair 7 (87.5%) having DWI all 8 (100%) lesions.

Acknowledgements: Author feels immense gratitude in thanking Geetanjali Medical College & Hospital For their valuable support.

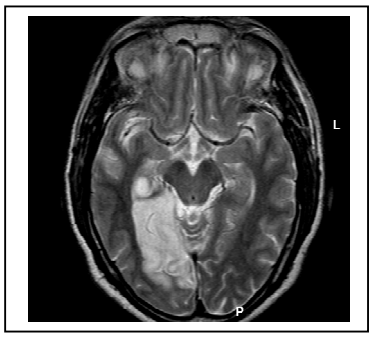


Figure I **PCA Infarct**

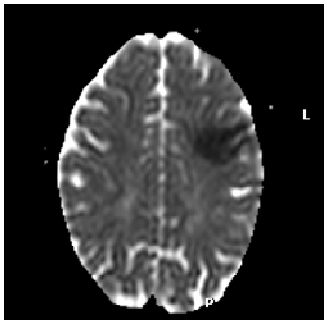


Figure II **Watershed Zone Infarct**

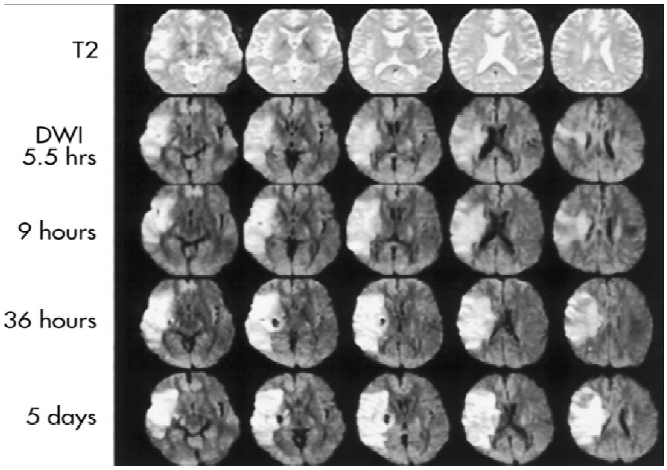


Figure III **Stages of Infarct**

LMCA Occluded

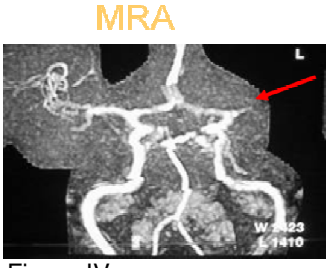
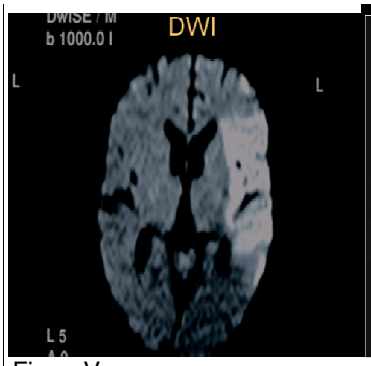


Figure IV



FigureV

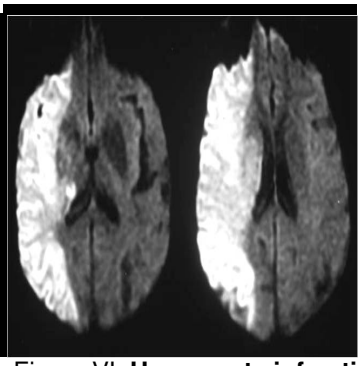


Figure VI **Hyperacute infarction (35 minutes)**

[**Hyperacute MCA Infarct]**

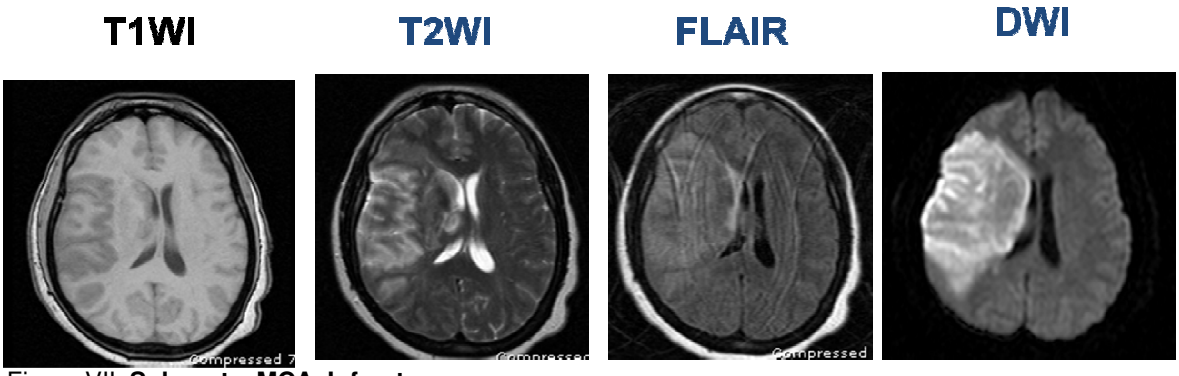


Figure VII **Subacute MCA Infarct**

Table 1 : Parameters followed for Diffusion Weighted Imaging

	TR	TE	FOV	FLIP ANGLE	SLICE THICKNESS
DW	2842	72	240	90	5mm
T1W Axial	596	15	240	69	5mm
T2W Axial	4479	100	240	90	5mm
T1W Sag	606	13	240	69	5mm
T1W Gd Axial	596	15	240	69	5mm
FLAIR	11000	120	240	90	5mm

www.ijbamr.com P ISSN: 2250-284X , E ISSN : 2250-2858

Table II : Table showing various pathologies detected by diffusion images.

(Total No. of cases 80 and Total No. of lesion 125)

CNS lesion	No. of cases N(%)	No of lesion N(%).
Infarct	50(62.5)	85(68.0)
Meningioma	10(12.5)	10(8.0)
H. Encephalitis	2(2.5)	7(5.6)
Epidermoid	3(3.75)	3(2.4)
Medulloblastoma	1(1.25)	1(8)
Subdural empyema	1(1.25)	1(8)
Abscess	7(8.75)	9(7.2)
Acute haematoma	4(5.0)	6(4J)
ADEM	2(2.5)	3(2.4)
Total	80(100)	125(100)

Table III : Distribution of cases of infarct

(Total number of cases = 50)

Cases distribution	**No.of cases N(%)**	**No of lesions**	**% of total lesions**
0-6hrs (hyperacute)	5(10)	8	9.41
Acute 6hrs-l week	36(72)	60	70.5
1-3weeks (Subacute)	4(8)	9	10.5
>3weeks (chronic)	3(6)	8	9.41
TIA	2(4)	0	0
Total	50(100)	85	100

www.ijbamr.com P ISSN: 2250-284X , E ISSN : 2250-2858

Table 4 Symptoms & Signs in patients with cerebral infarction &other intra cranial pathology

(No of cases= 80)

Symptoms & Signs	No. of Patients	%
1. Hemiparesis		
- Right side	25	31.2
- Left side	20	25
2. Monoparesis	7	8.7
3. Hemianesthesia	2	2.5
4. Facial nerve palsy	12	15
5. Headache	18	22.5
6. Fever &disorientation	7	8.75
7. Cerebellar symptoms	15	18.75
8. Unconsciousness	4	6.25

www.ijbamr.com P ISSN: 2250-284X , E ISSN : 2250-2858

Table V
Conventional MR features of cerebral infarction
(No. of cases = 50, no. of lesions = 85)

Conventional MR features	Hyperacute Infarct	Acute Infarct	Subacute Infarct	Chronic Infarct	Total	%
T1WI(Normal)	3	8	-	-	11	22
Iso to hypo intense lesions	2	28	4	3	37	74
T2WI(Normal)	1	2	-	-	3	6
Hyper intense lesions	4	34	4	3	45	90

Table VI : Fluid inversion recovery (FLAIR) **features of cerebral** infarction
(No. of cases = 50, no. of lesions =85)

Flair	Hyperacute	Acute	Subacute	Chronic	Total
Normal cases	1	1	-	-	2
Hyperintense	4	35	4	1	44
Hypointense with peripheral hyperintensity	-	-	-	2	2

www.ijbamr.com P ISSN: 2250-284X , E ISSN : 2250-2858

Table VII : Diffusion MR imaging features of cerebral infarction
(No. of cases = 50, No. of lesions = 85)

Diffusion MR	Hyperacute	Acute	Subacute	Chronic	Total
I a. Normal	0	2	-	-	21
b.Increasing hyperintensity from b0 to b1000	5	34	-	-	39
c.Decreasing hyperintensity from b0 to b1000	-	-	-	3	3
d.Isointense from b0 to bl000	-	-	4	-	4

Table VIII : Distribution of ischaemic lesions according to arterial territories
(No. of cases = 50, No. of lesions = 85)

Arterial Territory	Hyperacute	Acute	Subacute	Chronic	Total	%
1.ACA	-	5	-	-	5	5.8
2.MCA	7	31	4	4	46	54.1
3.PCA	-	10	2	2	14	16.4

www.ijbamr.com P ISSN: 2250-284X , E ISSN : 2250-2858

4.Watershed infarcts	1	4	1	1	7	8.2
5. Post circulation	-	10	2	1	13	15.2
Total	8	60	9	8	85	100

Table IX : Comparative analysis of conventional MR, FLAIR, and diffusion MR in the detection of cerebral infarction

Age of infarct	Conventional MR		FLAIR No. (%)	Diffusion MR No. (%)
	(T,WI) No. (%)	(T_2WI) No. (%)		
1. Hyperacute	2(25)	6(75)	7(87.5)	8(100)
2. Acute	48(80)	58(96.6)	58(96.6)	60(100)
3. Subacute	9(100)	9(100)	9(100)	9(100)
4. Chronic	8(100)	8(100)	8(100)	8(100)
Total	67(78.8)	81(95.2)	83(97.6)	85(100)

References

1. Andrew Kertesz, Sandra E Black et at. The sensitivity and specificity of MRI in stroke. Neurology 1987:37:1580-1585.

2. JS Tsuruda, WM Chew et al. Diffusion-weighted MR imaging of the brain; value of differentiating between extraaxial cysts and epidermoid tumors. American Journal of Roentgenology 1990, Vol 155,1059-1065.

3.Bryan RN et al. Diagnosis of acute cerebral infarction: comparison of CT and MR imaging. AJNR Am J Neuroradiol. 1991; 12:611- **20.**

4. Mark J Alberts, Michael C, Faulstich et al. Stroke with negative brain magnetic resonance imaging. Stroke 1992;23:663-667

5. Daisy chien, kwong et al. MRI of cerebral infarction in humans. AJNR 1992;13:1097-1102. Chien D Kwanf et al MR DWl in cerebral infraction in Human, JNR, Am J Neuroradiology 1992 July-Aug 13 (4) 1097-102.

6. Bestrice De Coene, Joseph V Hajnal et al. MR of the brain using 1LAIR pulse sequences. AJNR. 1992;13:1555-1564.

7.Decocnc JV, Hajnal, MRI of the brain stem, using FLAIR pulse sequences. Neuroradiology .1993;35:327-331

8. Warach S. Gaa J et al. Acute human stroke studied by whole brain E**P** DW MR imaging. Ann Neurology .1994;37(2):231 .

9.Tien RD, Feisberg OJ, Friedman et al MRI of high grade glioma : value of DWI **in** echoplaner pulse sequence. AJR Am J Roentgenol ; 671-7.

10. .Minematus K. Rinsho Shin Keigaka et al. Diffusion MR for cerebrovascular disease, 1995 Dec 35 (12) , 1575-7.

11. Sarensen AG1 Bgonatiros et al. Hyperacute stroke: evaluation wit**h** combined multisection DW **+** Hemodynamically weighted echo planar, Radiology 1996 May 199(2): 391-401.

12**.** Ebisu T, et al. Hemorrhagic and non hemorrhagic stroke : diagnosis with diffusion weighted and T2 W ecte plenor MR. Tanake Cl 4 Mede M Radiology 1997 ; June 203 (3); 823-8.

13. Krabbe et al MR DWI of Brain intracranial tumour, K1 Gideon P.Neuroradiology 1997, July 39 (7), 483-9.

14. Fjit H. Hirahuki N. et al. Epidermoid tumor of CP angle : signal loss in center lateral astern. AJNR. Am J Neuroradiology 1998 Feb 19(2), 333-5

15. Convol JC, oppenleim et al DW MRI in a case of cerebral venious thrombosis, stroke 1998; 29 (12): 264952.

16 . Kin YJ, Chang KH. et al Brain abscess + Necrotic or cystic brain tumor : discrimination with the signal intensity on DW **MRI** AJR, Am J Roentgenol 1998 Dec 171 (6): 1487-90,

17. Warach S, Gaaj et al. Acute human stroke studied by whole brain echoplanar DW MR, Ann Neurology 1995;37:231-241.

18. C. Fitzek, J. Tintera et al Differentiation of recent and old cerebral infarcts by diffusion-weighted MRI Neuroradiology Springer Berlin / Heidelberg Pages 778-782 vol 40 : number 12/dec 1998.

19. R. Gilberto Gonzalez , MD, PhD,Pamela W, Schaefer, MD et al. Diffusion – weighted MR Imaging : Diagnostic AccuracyIn Patients imaged within 6 hours of stroke symptom onset (Radiology, 1999; 210: 155-162.)