

Role of Diffusion MRI in Discrimination between Intracranial Cystic Lesions

Essay

Submitted for partial fulfillment of the Master degree in
Radiodiagnosis

Presented By

Mohamed Gamal Abd Elfattah Farrag
MB.B.Ch
Faculty of Medicine-Ain Shams University

Supervised by

Prof. Dr. Hanan Mahmoud Arafa
Professor of Radiodiagnosis,
Faculty of medicine-Ain Shams University

Dr. Merhan Ahmed Nasr
Lecturer of Radiodiagnosis,
Faculty of medicine-Ain Shams University

Ain shams university
Faculty of medicine
2016



First thanks to **ALLAH** to whom I relate any success in achieving any work in my life.

I wish to express my deepest thanks, gratitude and appreciation to *Prof. Dr. Hanan Mahmoud Arafa*, Professor of Radiodiagnosis, Faculty of medicine- Ain Shams University, for her meticulous supervision, kind guidance, valuable instructions and generous help.

Special thanks are due *Dr. Merhan Ahmed Nasr*, Lecturer of Radiodiagnosis, Faculty of medicine- Ain Shams University, for her sincere efforts and fruitful encouragement.

Last but not least, I thank all patients and subjects participated in this work

Dr. Mohamed Gamal Abd Elfattah Farag



وَأَنْزَلَ اللَّهُ عَلَيْكَ الْكِتَابَ
وَالْحِكْمَةَ وَعَلَّمَكَ مَا لَمْ تَكُنْ
تَعْلَمُ وَكَانَ فَضْلُ اللَّهِ
عَلَيْكَ عَظِيمًا

﴿صُرِّقَ اللَّهُ الْعَظِيمُ﴾

﴿الْآيَةُ (١١٢) سُورَةُ النِّسَاءِ﴾

List of Contents

<i>Title</i>	<i>Page No.</i>
List of Abbreviations.....	
List of Figures	
Introduction	
Aim of the work	
Anatomiyof the brain	
- Gross anatomy	
- MRI anatomy	
Physical Principles of DWI.....	
- Techniques of DWI.....	
- Protocol for DWI and ADC map	
- Normal brain DWI	
Pathology of Intracranial Cystic Mass Lesions.....	
MRI findings in intracranial cystic mass lesions	
Illustrative cases	
Summary and Conclusion	
References	
Arabic summary	

List of Abbreviations

AA	Anaplastic astrocytoma
AC	Arachnoid Cyst
ACA	Anterior cerebral artery
ACoA	anterior communicating artery
AC-PC	Anterior commissure–Posterior commissure
ADC	Apparent Diffusion Coefficient
ADCr	Apparent Diffusion Coefficient ratio
CCs	Colloid cysts
CNS	Central Nervous System
CPA	Cerebellopontine angle
CPCs	Choroid Plexus Cysts
CPs	Craniopharyngiomas
CSF	Cerebrospinal fluid
dMRI	Diffusion MRI
DWI	Diffusion weighted image
ECs	Epidermoid Cysts
EPI	Echo planar imaging
FLAIR	Fluid attenuation inversion recovery
GBM	Glioblastoma Multiform
HBL	Hemangioblastoma
ICA	Internal carotid artery
LGA	Low-grade astrocytoma
MRI	Magnetic resonance imaging
NCC	Neurocysticercosis

NGCs	Neuroglial Cyst
PAs	Pilocytic astrocytoma
PC	Pineal Cyst
PCA	Posterior cerebral artery
PCoAs	Posterior communicating arteries
PNS	Paranasal sinuses
PVSs	Enlarged Perivascular Spaces
RCCs	Rathke's cleft cysts
RF	Radiofrequency
ROI	Region of interest
SENSE	SENSitivity Encoding
SI	Signal intensity
T1WI	T1 weighted image
T2WI	T2 weighted image
TE	Time to echo
TR	Time to repeat
VHL	Von Hippel- Lindau
WHO	World Health Organization

List of Figures

<i>Fig. No.</i>	<i>Title</i>	<i>Page No.</i>
Fig. (1):	Cerebrum: Lateral Views Quoted from (Netter, 2014).	6
Fig. (2):	Basal Nuclei (Ganglia) Quoted from (Netter, 2014).	7
Fig. (3):	Cerebellum Quoted from (Netter, 2014).	8
Fig. (4):	Postero lateral view of the brain stem Quoted from (Netter, 2014).	9
Fig. (5):	Ventricles of the Brain Quoted from (Netter, 2014).	10
Fig. (6):	Cerebral Arterial Circle of Willis Quoted from (Netter, 2014).	12
Fig. (7):	Dural Venous Sinuses Quoted from (Netter, 2014).	14
Fig. (8):	Axial MR image showing the lateral ventricles. quoted from (Applegate, 2010).	17
Fig. (9):	T2 axial MRI through the thalamus and third ventricle. quoted from (Cochard et al., 2012).	18
Fig. (10):	Axial T1 MRI scan at the level of the fourth ventricle Quoted from (Xu et al., 2009).	19
Fig. (11):	Coronal T1 MRI scan at the level of the third ventricle Quoted from (Xu et al., 2009).	20
Fig. (12):	T2 flair coronal MRI through the brainstem. quoted from (Cochard et al., 2012).	21
Fig. (13):	T2 flair coronal MRI through the cerebellum netter. quoted from (Cochard et al., 2012).	22
Fig. (14):	Midsagittal MR image of the brain.quoted from (Applegate, 2010).	23
Fig. (15):	T1 sagittal MRI through the temporal lobe. quoted from (Cochard et al., 2012).	24
Fig. (16):	Measuring water diffusion. Stejskal and Tanner adopted T2-weighted spin-echo sequence for measuring water diffusion. They applied symmetric diffusion-sensitizing gradient around 180° refocusing pulse. On this schematic drawing, stationary molecules are unaffected by gradients and measured signal intensity is preserved. By contrast, moving water molecules acquire phase information from first gradient, which is not entirely rephased by second gradient, thereby leading to signal loss. Hence, water diffusion is detected as attenuation of measured MR signal intensity. RF	

= radiofrequency pulse Quoted from (Koh and Collin, 2007).....	27
Fig. (17): The bundle offers no resistance to water molecules in the diffusion direction parallel to the fibers but there is a severe restriction if perpendicular. In this case there is preferred water molecule direction due to anisotropy. Outside the bundle, the water molecules are in an isotropic environment and have no preferred direction Quoted from (De Figueiredo et al., 2011).....	29
Fig. (18): Calculation of signal intensity on an isotropic DW image. The signal intensities of the three transverse images (Gx, Gy, and Gz), each with a diffusion gradient applied in one of three orthogonal directions, are multiplied together. Here the DW gradients were applied along the x, y, and z axes. The signal intensity of the isotropic DW image (bottom) is essentially the cube root of the signal intensities of these three images multiplied together Quoted from (Schaefer et al., 2000).....	32
Fig. (19): Normal adult brain of a 40-year-old male without neurological deficits. (a) Isotropic DW image is obtained by combining b0 image and three orthogonal unidirectional images (x, y, z axis). The bilateral globi pallidi have low signal on DW image as a result of physiological iron deposition (arrows). Corticospinal tracts have mildly high signal on DW image (arrowheads). Gray matter shows mildly high signal compared to white matter. These signal changes on isotropic DW imaging are normal and are caused by T2 contrast. (b)ADC map shows homogeneous ADC values in globi pallidi, corticospinal tracts, gray and white matter. (c) b0 image shows low signal in globi pallidi (arrows), high signal in corticospinal tracts (arrowheads), and the gray–white matter contrast. Quoted from (Moritani et al., 2009).	39
Fig. (20): Cystic changes in the choroid plexus. (a) DW image shows hyperintensity in cystic changes of the left choroid plexus (arrow). (b) ADC values of the cystic changes are lower than those of the CSF, which probably represent viscous gelatinous materials, but higher than those of brain parenchyma (arrow). (c) T2-weighted image shows the cystic changes as hyperintensity (arrow). (d) Gadolinium-enhanced T1-weighted image with magnetization transfer	

contrast reveals no enhancement in it (arrow) Quoted from (Moritani et al., 2009).....	40
Fig. (21): Normal neonatal brain. (a) The appearance of the pediatric brain on DW images varies with age. In neonates it is normal to have low DW signal intensities in the frontal deep white matter (arrows). (b) ADC values of the corresponding areas are high in neonatal brain, especially in the white matter (arrows). Quoted from (Moritani et al., 2009).....	41
Fig. (22): Classification of Intracranial Cystic mass lesions according to origin or pathogenesis Quoted from (Osborn and Preece, 2006).....	42
Fig. (23): The cut surface of the cerebrum reveals gelatinous cysts in the glomera of the bilateral lateral ventricles. The arrow points to a choroid plexus cyst on the right side quoted from (Kinoshita et al., 2005)..	44
Fig. (24): Submentovertex view of autopsied brain with large middle fossa arachnoid cyst, which is contained within split layers of arachnoid Quoted from (Osborn and Preece, 2006).....	46
Fig. (25): Dermoid cyst. A ball of hair (bottom) and a mixture of tissues are evident quoted from (Sattar, 2013).	48
Fig. (26): Sagittal graphic representation shows posterior fossa epidermoid cyst (arrow) wrapping around basilar artery and displacing the brain stem posteriorly Quoted from (Osborn and Preece, 2006).....	49
Fig. (27): Removed Hydatid cysts are seen after operation. Quoted from (Per et al., 2008).....	51
Fig. (28): Age distribution Quoted from (Muzumdar et al., 2011).	53
Fig. (29): Classification of Intracranial Cysts according to Most Common Location Quoted from (Osborn and Preece, 2006).	54
Fig. (30): Bilateral CPCs. a The axial contrast-enhanced T1-weighted image shows nonenhancing choroid plexus cysts with enhanced thick rims in the trigones of the bilateral lateral ventricles. b The axial FLAIR image shows mildly high signal intensities in the bilateral choroid plexus cysts. c The axial diffusion-weighted image reveals high signal intensities in bilateral CPCs. d The corresponding ADC map demonstrates slight hypointensity in the bilateral CPCs. Quoted from (Kinoshita et al., 2005).....	63
Fig. (31): Transverse FLAIR MR image shows ependymal cyst within enlarged atrium of the left lateral ventricle (open arrow).	

- Signal intensity was iso intense to CSF at all pulse sequences. Note lateral displacement of choroid plexus (solid arrow) Quoted from (Osborn and Preece, 2006).64
- Fig. (32): Bilateral VR spaces in a 6-year-old boy. (a) Axial proton-density– weighted image shows hyperintense areas (arrows) in the anterior perforated substance on both sides. (b) Axial FLAIR image obtained at the same level shows that these areas have CSF-like content (arrows). The signal intensity of the surrounding brain parenchyma is normal. (c) Diffusion-weighted image and corresponding apparent diffusion coefficient map (d) show no restricted diffusion in these areas (arrows) quoted from (Kwee and Kwee, 2007).65
- Fig. (33): MRI of NGC showing a purely cystic lesion on T1W (a), and T2W (b) sequences. No enhancement was noted on post contrast images Quoted from (Verma et al., 2012).66
- Fig. (34): Pineal cyst (incidentally found in an evaluation for multiple sclerosis) in a 32-year-old woman. Axial postcontrast T1-weighted MR image shows a round, low-signal-intensity, 8-mm lesion in the pineal region, a finding consistent with a cyst. The lesion has a thin incomplete enhancing rim (arrow). No nodularity of the wall and no associated hydrocephalus are seen quoted from (Smith et al., 2010).67
- Fig. (35): 39 y female with right CPA arachnoid cyst. the cyst show the same intensity of CSF in T2, FLAIR and DWI quoted from (Hakyemez et al., 2003).68
- Fig. (36): ECs iso intense to CSF on T2WI, but demonstrates restriction on diffusion quoted from (Hakyemez et al., 2003).69
- Fig. (37): CC Round, well-demarcated lesion of third ventricle, hypointense on T2-weighted and hyperintense on T1-weighted Quoted from (Oprisan and Popescu, 2013).70
- Fig. (38): Ruptured dermoid cyst in a 44-year-old woman. Sagittal T1-weighted MR image shows an ovoid, heterogeneously hyperintense midline suprasellar mass (arrow) and numerous punctate high-signal-intensity foci scattered throughout the subarachnoid space quoted from (Ginat and Meyers, 2012).72
- Fig. (39): The neuroenteric cyst contents are hyperintense on T1W sagittal image Quoted from (Hingwala et al., 2013).73
- Fig. (40): Rathke’s cleft cyst. Coronal enhanced T1-weighted MR image demonstrates a mass (star) isointense to cerebrospinal fluid with a thin enhancing wall protruding into the

suprasellar cistern. The optic chiasm is indicated by the arrow quoted from (Pisaneschi and Kapoor, 2005).	74
Fig. (41): Coronal T1-weighted MR image shows enlarged left temporal horn (black arrow) that communicates with peripherally located porencephalic cyst (white arrows). Cyst extends to the brain surface Quoted from (Osborn and Preece, 2006).	75
Fig. (42): Parenchymal form of NCC: a) Axial T1 W1 - cystic lesion with ring enhancement; b) Diffusion W1 – cystic lesion with bright scolex; c) Diffusion map - cystic lesion with same signal tha CSF quoted from (Raffin et al., 2001).....	77
Fig. (43): Axial T2WI, showing the gigantic RT parietal hydatid cyst Quoted from (Per et al., 2008).	78
Fig. (44): (a) Sagittal precontrast T1-weighted MR image in a patient presenting to the emergency room with seizure shows partially cystic mixed-signal-intensity subcortical mass (arrow). (b) Transverse postcontrast T1-weighted MR image demonstrates some enhancement around complex cystic mass (arrow). Surgery disclosed multiloculated amebic abscess Quoted from (Osborn and Preece, 2006).....	79
Fig. (45): Magnetic resonance images of a brain abscess. A T2-weighted image (A) showing an abscess in the right frontal lobe with a complete thin hypointensity rim surrounded by vasogenic edema. A Gd-enhanced T1-weighted image (B) showing the corresponding rim of enhancement. A DW image (C) and ADC ratio (D)showing hyperintense and hypointense signals, respectively, consistent with restricted diffusion. quoted from (Fertikh et al., 2007).	80
Fig. (46): (a and b) DWI of fungal abscess show restricted diffusion in periphery (black arrow) and non-restricted diffusion at the center in some lesions with other lesions showing restricted diffusion both at periphery and the center (black arrow head). (C and d), ADC images show low values in the projections and high values in the cavity Quoted from (Kamalapur et al., 2011).	81
Fig. (47): Gadolinium-enhanced brain MRI. The lesion is hypointense on T1- and hyperintense on T2-weighted images (asterisk). A small mural nodule is observed. After gadolinium administration, enhancement of the small mural nodule (white arrow) and of the peripheral cystic area is observed Quoted from (Jorge et al., 2014).....	83

- Fig. (48): Diffusion-weighted image (DWI) and apparent diffusion coefficient (ADC) map image. The cystic portion of the lesion shows facilitated diffusion, although slightly more restricted than CSF Quoted from (Jorge et al., 2014).84
- Fig. (49): Three subtypes of acoustic neuroma based on MRI appearance: (a) Type A: large, single cystic region with relatively small amount of peripheral solid tumor. (b) Type B: cystic region within a largely solid tumor mass. (c) Type C: multicystic tumor Quoted from (Wandong et al., 2005).85
- Fig. (50): (a) T1-weighted, axial and (b) T2-weighted, axial MRI of a cystic hemangioblastoma localized in the left cerebellar hemisphere, showing the characteristic mural nodule with strong gadolinium enhancement Quoted from (Brundl et al., 2014).86
- Fig. (51): Adamantinomatous CP in a 12-year-old boy with headache and blurred vision. Sagittal unenhanced (a) and coronal contrast-enhanced (b) T1-weighted MR images show a lobulated suprasellar tumor with intrasellar extension. The tumor is formed predominantly of multiple cysts with varying signal intensities that show thin mural contrast enhancement (arrows in b). quoted from (Saleem et al., 2007).88
- Fig. (52): Juvenile pilocytic astrocytoma in a 10-year-old boy89
- Fig. (53): A 44-year-old man with a grade II diffuse astrocytoma90
- Fig. (54): T2 shine-through in a 45-year-old female patient with seizures caused by an anaplastic astrocytoma. a T2 weighted image shows a hyperintense lesion in the left frontal lobe (arrow). b On T1-weighted image the lesion is hypointense with a peripheral hyperintense area (arrow). The lesion did not enhance with contrast (not shown). c DW image shows hyperintensity (arrow). d ADC map also shows hyperintensity in the lesion ($0.98\text{--}1.35 \times 10^{-3} \text{ mm}^2/\text{s}$; arrow). e Exponential image eliminates the T2 effect and shows the lesion to be hypointense (arrow). This confirms that the hyperintensity on the DW image is due to a T2 shine-through effect Quoted from (Moritani et al., 2009).91
- Fig. (55): GBM in the right temporal lobe. A, T2-weighted image showing tumor of mixed intensity with peritumoral edema. B, The tumor shows heterogeneous enhancement after intravenous injection of contrast medium. C, On DWI, a solid portion of the tumor is isointense to moderately high

in intensity, and edema is isointense quoted from (Kono et al., 2001).	92
Fig. (56): A 63-year-old man with large cell neuroendocrine carcinoma from the lung.....	94
Fig. (57): A: Axial T2-weighted image shows a hyperintense lesion. B: Contrast-enhanced T1-weighted MR image reveals no enhancement of the hypointense lesion. C: Diffusion-weighted image shows hypointense signal of the lesion. D: Apparent diffusion coefficient map reveals hyperintensity. arachnoid cyst proven by surgical insertion of shunt catheter for drainage of the cerebrospinal fluid in the pineal region quoted from (Lai et al., 2007).	96
Fig. (58): (a) T2-weighted image shows a hyperintense mass (arrow) in the left CPA. (b) Gadolinium-enhanced T1 weighted image with magnetization transfer contrast shows the lesion (arrow) as hypointense with no enhancement. (c) DW image shows this lesion (arrow) as hyperintense. (d) ADC map shows almost similar ADC value to the cerebellar parenchyma. Case of Epidermoid cyst Quoted from (Moritani et al., 2009).	97
Fig. (59): (a)Axial T2 WIs showing left temporoparietal hyperintense T2 lesion. (b)Her contrast enhanced MRI shows a marginally enhancing lesion at the left temporoparietal region with central breaking down. (c) DWI show facilitated diffusion. pathologically proven glioblastoma multiformes.quoted from (Hassan et al., 2012).	98
Fig. (60): (a) T1WI also shows a complete ring, which may be slightly hyperintense (from hemorrhage versus free radicals). (b) T2WI with hypointensity in the ring. Surrounding vasogenic edema is high intensity. (c) Postcontrast T1WI demonstrates the thin ring enhancement. (d) DW imaging with very bright central region, consistent with pyogenic brain abscess. quoted from (Yousem and Grossman, 2009).	99
Fig. (61): (a) On T2-weighted fast spin-echo image, the solid portion of a right parietal mass lesion (arrow) is hyperintense relative to the normal-appearing white matter. (b) On contract-enhanced T1WI, the peripheral region of the lesion is enhanced (arrow). (c) On DWI, the lesion is hyperintense relative to the normal-appearing cortical gray matter (arrow). (d) On ADC map, the solid lesion is slightly hyperintense. Consistent with intracerebral metastasis. Quoted from (Hayashida et al., 2006).....	100

Fig. (62): (a) T2WI shows a hyperintense cystic mass in the cerebellum and hydrocephalus. There is a mural nodule (arrow) in the tumor. (b) Gadolinium-enhanced T1WI shows enhancement in the nodule. (c) DW image shows hypointensity in the cystic component and isointensity in the nodule. (d) ADC map shows hyperintensity in the cystic component and hyperintensity in the nodule. consistent with Pilocytic Astrocytoma. Quoted from (Moritani et al., 2009).....	101
Fig. (63): (a) T2 WI shows a hyperintense mass (arrow) in the suprasellar region. (b) DW image shows hypointensity in the mass (arrow). (c) ADC map shows hyperintensity. case of Craniopharyngioma.quoted from (Moritani et al., 2009).	102
Fig. (64): (a) Postcontrast T1W MRI demonstrates ring enhancement, and FLAIR (b) confirms extensive vasogenic edema. (c) DWI demonstrates no restricted diffusion centrally, helping to differentiate this lesion from pyogenic abscess. Needle guided biopsy of a lung mass revealed non-small cell lung cancer. The patient underwent stereotactic radiosurgery of the brain mass for presumed lung cancer metastasis.Quoted from (Fink and Fink, 2013).	103
Fig. (65): (a) Axial T1WI of the brain without contrast showing all the three cysts, noted as '1', '2' and '3'; (b) Axial T1WI of the brain with contrast. There is no enhancement of the wall of the cysts after the administration of gadolinium.....	104
Fig. (66): Axial DWI showing the lateral and central cysts without restricted diffusion. Case of Enlarged Peri Vascular (Virchow-Robin) Spaces. Quoted from (Sankararaman et al., 2013).	104
Fig. (67): Axial unenhanced (a), axial contrast-enhanced (b) T1-weighted images show cystic mass in cerebellum with homogeneously enhancing mural nodule medially; these findings are consistent with hemangioblastoma. (d) FLAIR image shows solid component of mass to be hyperintense to gray matter. (e) DWI Solid component of mass shows no restricted diffusion. quoted from (Plaza et al., 2013).	105

INTRODUCTION

Diffusion-weighted (DW) magnetic resonance (MR) imaging provides potentially unique information on the viability of brain tissue. It provides image contrast that is dependent on the molecular motion of water, which may be substantially altered by disease (**Schaefer et al., 2000**).

DWI is a MRI technique that measures tissue water diffusional motion and provides information about orientation, size and geometry of the tissue. Pathological processes that modify tissue organization can cause abnormal water motion with the consequence of altered apparent diffusion coefficient (ADC) values (**Tavazzi et al., 2007**).

DW-MRI characterized by markedly decreased imaging time and increased sensitivity to signal changes due to molecular motion. But having the disadvantages of decreased spatial resolution of the images and magnetic field inhomogeneities which is partially prominent in anatomic regions with air-tissue interfaces, such as the base of the skull. (**Hagmann P, et al., 2006**).

DWI provides a novel way to evaluate the diffusion properties of the water molecules in tissue and has been used in clinical applications such as ischemia, tumors, epilepsy, and