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Magnetic Resonance Imaging Features of Common Posterior Fossa Brain Tumors in Children: A Preliminary Vietnamese Study

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Abstract

BACKGROUND: Magnetic Resonance Imaging (MRI) nowadays plays an important role in the evaluation of posterior fossa brain tumours in children for appropriate diagnosis, treatment planning, and follow-up.

AIM: To assess the MRI features of common posterior fossa brain tumours including medulloblastomas, ependymomas, and pilocytic astrocytomas along with the postoperative parameters to contribute the local knowledge to the neuroradiology and neurosurgery fields.

METHODS: The study was performed at Children's Hospital 02 from January 2016 to June 2019. In this study, all pediatric patients adopted MRI to evaluate the posterior fossa brain tumours' characteristics and then underwent surgery to eradicate the posterior fossa tumours. We retrospectively compared the baseline parameters, MRI parameters, and postoperative parameters among medulloblastomas, ependymomas, and pilocytic astrocytomas.

RESULTS: There were 62 patients (27 medulloblastomas, 20 ependymomas, and 15 pilocytic astrocytomas) in this research. The main structure of medulloblastomas and ependymomas was predominantly solid, whereas the main structure of pilocytic astrocytomas was superiorly cystic ($p < 0.05$). Ependymoma tended to extend tumour through foramina of Luschka and Magendie ($p < 0.05$). Medulloblastomas chiefly showed iso intensity on T2W and FLAIR images meanwhile ependymomas and pilocytic astrocytomas predominantly appeared hyperintensity on T2W and FLAIR images. Medulloblastomas and ependymomas were mostly high intensity on DWI, and low intensity on ADC whereas pilocytic astrocytomas were usually low intensity on DWI and high intensity on ADC. After injecting CE, pilocytic astrocytomas showed a mixed intensity whereas the signal intensity of medulloblastoma and ependymoma on T1CE was generally strong. There were positive correlations between FH diameter and estimated blood loss ($r = 0.289$, $p < 0.05$); and surgical time ($r = 0.312$, $p < 0.05$).

CONCLUSION: MRI plays a crucial role in demonstrating the features of posterior fossa brain tumours for appropriate diagnosis of medulloblastomas, ependymomas, and pilocytic astrocytomas. Medulloblastomas are problematic tumours and the clinicians should also take into consideration in cases of larger feet-to-head diameter of tumours to ensure the efficacy and safety surgery for patients.

Introduction

Viet Nam, the second most crowded nation positioned in South East Asia, is economically classified as a developing country in the world. Ho Chi Minh city is the largest city located in the south of the country with nearly 10 million people living there, of whom about 20-25% were under 15-year-old with the male to female ratio at birth is 1.122 [1], [2]. Intra-axial cranial tumours are the second commonest neoplasm following leukaemia in children occurring in 2.4 to 4 per 100,000 people. In children, primary intra-axial supratentorial brain tumours account for 30-40% [3]. Whereas, infratentorial brain tumours occupy approximately 60 – 70% of all brain tumours [4].

In a previous study, the result showed that the incidence of brain cancer in Vietnam is 2.2 per 100000 for male and 1.4 per 100000 for female. Meanwhile, the percentage of brain cancer in male and female children was 18.1% and 17.2%, respectively [1]. In reports issued by Central Brain Tumor Registry of the United States, the findings revealed that brain tumours have an incidence of 5.47 per 100,000 children under 14-year-old. It is critical that the most common tumours, leading the cause of cancer-related death were posterior fossa brain tumours (medulloblastomas, ependymomas, and pilocytic astrocytomas) [5], [6], [7], [8].

The incidence of pediatric brain tumours in Vietnam is lower than that of other countries due to some following reasons [2]. Vietnamese radiology was

legitimately established after Victory Dien Bien Phu by 1954, which was the end of the war against French invasion. Then, Vietnam was suffered from the war against the United States until 1975. Thus, radiology has just developed for nearly 45 years. Even though MRI nowadays plays an important role in the evaluation of brain tumours for appropriate diagnosis, treatment planning and follow-up, approximately 80% of the Vietnamese cities and central hospitals owned only 51 magnetic resonance imaging (MRI) systems by 2009 [9].

Therefore, it is an apparent fact that there was an under-assessment brain tumour for children in Vietnam due to the insufficiency of non-invasive and innovative MRI modality [2]. Also, there are only nine hospitals in Vietnam where the appropriate evaluation and surgery for patients with brain tumours can be carried out efficaciously (4 in Ha Noi, 1 in Da Nang and 4 in Ho Chi Minh city) [10]. Currently, there is no systematic MRI study about pediatric posterior fossa brain tumours in Vietnam. Hence, in this study, we aimed to assess the MRI features of common posterior fossa brain tumours in children including medulloblastomas, ependymomas and pilocytic astrocytomas along with the postoperative parameters to contribute the local knowledge to the neuroradiology and neurosurgery fields.

Material and Methods

Ethical consideration

Institutional Review Board of Children's Hospital 02 approved this retrospective study (745 / ND2-CDT).

Patient population

The study was carried out in the Department of Radiology and Department of Neurosurgery, Children's Hospital 02 from January 2016 to June 2019. In this research, all pediatric patients adopted MRI to evaluate the tumours' characteristics before treatment. Then, patients underwent surgery to eradicate the posterior fossa tumours. Histopathological samples were analysed by histopathologist who had 8-year experience in interpreting brain tumours.

MRI protocol

Before 2019, MRI 1.5T scanners were utilised (Essenza, Siemens, Erlangen, Germany and Optima, GE Healthcare, Milwaukee, The United States of America). By 2019, Scanning was additionally performed by 1.5T Multiva, Philips Medical Systems, Best, the Netherlands. All MRI images were interpreted by two certificated MRI radiologists (NMD and MTLB) with over 10-year experience. It is noted that MRI protocols were the same and fully approved by both radiology and neurosurgery departments including non-contrast sagittal T1-weighted imaging (T1W); axial T2-weighted imaging (T2W), coronal T2-Fluid-Attenuated Inversion Recovery (FLAIR), axial gradient-recalled echo T2*WI, axial Diffusion-weighted imaging (DWI) with apparent diffusion coefficient (ADC) and axial T1-weighted with contrast enhancement (CE) (T1CE) (0.1 ml/kg-Gadovist, Bayer, Germany or 0.2ml/kg-Dotarem, Guerbet, France).

Parameters

Baseline parameters included the age, sex, symptoms, tumour location, tumour diameters (anterior-posterior (AP); right-left (RL); and feet-head (FH)), tumour characteristics (main structure, components, dilated ventricle, peritumoral oedema, and tumour extension). MRI parameters were comprised of signal intensity (SI) of T1W, T2W, FLAIR, DWI, ADC, and T1CE.

Postoperative parameters included tumour histology, estimated blood loss, surgical time, time at intensive care unit, and total hospital admission time.

Data collection and Statistics

Data were collected and stored on a spreadsheet (Excel 2010; Microsoft, Redmond, Washington). Data were analysed by SPSS version 23 (IBM, Armonk, New York). Continuous variables were introduced as mean ± standard deviation and range meanwhile nominal variables were presented as percentage or number of cases. Nominal variables were compared by performing Fisher's exact test. Continuous variables were compared by exploiting the Anova with or without Post-Hoc test if appropriate. Pearson correlation test is used to investigate the relationship between two continuous variables. The observed differences were statistically significant if the p-value was less than 0.05 ($p < 0.05$).

Results

Baseline parameters

As shown in Table 1, there are 62 pediatric patients (male/female = 1.07/1) with mean age: 6.73 years ± 3.50 (1-15). Medulloblastomas were more dominant in male than in female meanwhile ependymomas and pilocytic astrocytomas were more common in female than in male.

Table 1: Baseline characteristics

Baseline parameters	Overall n = 62	Medulloblastoma n = 27	Ependymoma n = 20	Pilocytic astrocytoma n = 15	P value
Age (years)	6.73 ± 3.50 (1-15)	7.79 ± 2.96 (2-15)	4.50 ± 2.85 (1-11)	7.60 ± 3.94 (2-15)	0.002*[α]
Gender					0.019*[β]
Female	30 (48.4%)	8	11	11	
Male	32 (51.6%)	19	9	4	
Symptoms					0.201
Headache	33 (53.2%)	14	10	9	
Vomiting	13 (21%)	10	2	1	
Muscle weakness	6 (9.7%)	1	3	2	
Ataxia	3 (4.8%)	1	1	1	
Unconsciousness	3 (4.8%)	1	2	0	
Epilepsy	1 (1.6%)	0	1	0	
Faint	1 (1.6%)	0	0	1	
Sensory disorder	1 (1.6%)	0	0	1	
Dysmetria	1 (1.6%)	0	1	0	
Location					< 0.001*[β]
Fourth ventricle	41 (66.1%)	21	19	1	
Vermis	9 (14.5%)	2	1	6	
Right cerebellar hemisphere	7 (11.3%)	2	0	5	
Left cerebellar hemisphere	5 (8.1%)	2	0	3	
Diameters					
RL (mm)	48.82 ± 11.01 (21-83)	47.81 ± 9.70 (21-62)	45.00 ± 9.72 (25-63)	55.73 ± 12.29 (32-83)	0.012*[α]
AP (mm)	45.69 ± 11.67 (17-67)	44.07 ± 10.70 (20-67)	41.75 ± 10.04 (17-55)	53.83 ± 12.01 (25-67)	0.005*[α]
FH (mm)	46.63 ± 11.45 (16-68)	44.41 ± 9.98 (17-63)	46.00 ± 13.82 (16-68)	51.47 ± 9.54 (30-65)	0.153
Main structure					< 0.001*[β]
Solid	37 (59.7%)	22	14	1	
Mixed	15 (24.2%)	5	6	4	
Cyst	10 (16.1%)	0	0	10	
Components					< 0.001*[β]
Cyst inside tumor	18 (29.0%)	1	2	15	
Necrosis	17 (27.4%)	10	7	0	
Hemorrhage	8 (12.9%)	6	2	0	
Calcification	2 (3.2%)	1	1	0	
Peritumoral edema	21 (33.9%)	12	5	4	0.302
Dilated ventricle	55 (88.7%)	25	17	13	0.689
Tumor extension					0.016*[β]
Magendie foramina	7 (11.3%)	2	5	0	
Left Luschka foramina	4 (6.5%)	1	3	0	
Right Luschka foramina	3 (4.8%)	0	2	1	
Both Luschka foramina	2 (3.2%)	0	2	0	
Sylvius aqueduct	2 (3.2%)	1	1	0	

* Statistically significant; [α] Anova test; [β] Fisher's exact test.

The mean age of ependymoma was significantly lower than the two other types ($p < 0.05$). Two most common locations of tumours were fourth ventricle and vermis. The means of three diameters (AP, RL, and FH) of pilocytic astrocytomas were higher than those of two other types. The main structure of medulloblastomas and ependymomas was predominantly solid whereas the main structure of pilocytic astrocytomas was superiorly cystic ($p < 0.05$).

Necrosis and haemorrhage were observed more commonly in medulloblastomas and ependymomas; meanwhile, pilocytic astrocytomas mostly contains cyst inside the tumours ($p < 0.05$). Peritumoral oedema was significantly higher in patients with medulloblastomas than in two other types ($p < 0.05$). Ependymomas tended to extend tumours through foramina of Luschka and Magendie ($p < 0.05$).

MRI parameters

As shown in Table 2, medulloblastomas chiefly showed isointense on T2W and FLAIR images meanwhile ependymomas, and pilocytic astrocytomas predominantly appeared hyperintensity on T2W and FLAIR images. Medulloblastomas and ependymomas were mostly high intensity on DWI, and low intensity on ADC whereas pilocytic astrocytomas were usually low intensity on DWI and high intensity on ADC. After injecting CE, pilocytic astrocytomas showed a mixed intensity whereas the signal intensity of medulloblastomas and ependymomas on T1CE was generally strong.

Table 2: MRI characteristics

MRI parameters	Overall n = 62	Medulloblastoma n = 27	Ependymoma n = 20	Pilocytic astrocytoma n = 15	p
T1W					0.474
Hypointense	58 (93.5%)	25	18	15	
Mixed	4 (6.5%)	2	2	0	
T2W					< 0.001*[β]
Hyperintense	45 (72.6%)	10	20	15	
Isointense	15 (24.2%)	15	0	0	
Mixed	2 (3.2%)	2	0	0	
FLAIR					< 0.001*[β]
Hyperintense	27 (43.5%)	7	14	6	
Isointense	17 (27.4%)	16	1	0	
Mixed	13 (21%)	4	5	4	
Hypointense	5 (8.1%)	0	0	5	
DWI					< 0.001*[β]
Hyperintense	39 (62.9%)	23	16	0	
Hypointense	23 (37.1%)	4	4	15	
ADC					< 0.001*[β]
Hypointense	39 (62.9%)	23	16	0	
Hyperintense	23 (37.1%)	4	4	15	
T1CE					< 0.001*[β]
Strong	35 (56.5%)	20	14	1	
Mixed	17 (27.4%)	0	3	14	
Slight	10 (16.1%)	7	3	0	

* Statistically significant; [β] Fisher's exact test.

Postoperative parameters

As shown in Table 3, ANOVA test showed that there was no significant difference among total admission time, estimated blood loss, intensive care unit time and surgical time among three groups. Nonetheless, Post-Hoc test revealed that total hospital admission time and intensive care unit time of patients with medulloblastomas were significantly higher than those of patients with pilocytic astrocytomas ($p = 0.008$ and $p = 0.045$, respectively).

Correlation test

It is observed that there were weak positive correlations between FH diameter and estimated blood loss ($r = 0.289$, $p < 0.05$, Pearson test); and surgical time ($r = 0.312$, $p < 0.05$, Pearson test). Meanwhile, there was a moderate positive correlation between surgical time and estimated blood loss ($r = 0.485$, $p < 0.05$, Pearson test).

Discussion

In this clinical study, we focused only the three most common posterior fossa brain tumours including medulloblastomas, ependymomas, and pilocytic astrocytomas. We observed that there were

significant differences between age and gender among these groups. In a previous study, mean ages of medulloblastomas, ependymomas, and pilocytic astrocytomas were 6.2; 4.7; and 6.2, respectively. Moreover, the male to female ratios for medulloblastomas, ependymomas, and pilocytic astrocytomas were 1.3/1; 0.67/1; and 1.12/1 [11]. Meanwhile, in our study, mean ages for medulloblastomas, ependymomas, and pilocytic astrocytomas were 7.79; 4.50; and 7.60. Furthermore, the male to female ratios for medulloblastomas, ependymomas, and pilocytic astrocytomas in this present study were 2.37/1; 0.82/1; and 0.36/1. In many literature papers, medulloblastomas, accounting for 40% of posterior fossa tumors, more prevailing in male, are usually seen before 7-year-old whereas ependymomas, accounting for approximately 20% of the posterior fossa tumours in children with a slight increase of incidence in boys, have a peak incidence in younger pediatric patients from 3- to 5-year-old [12], [13]. On the other hand, pilocytic astrocytomas, making up 30% of posterior fossa tumours, appearing between the ages of 5- to 13-year-old [12], [13], [14], have an equal incidence between girls and boys [15]. Although there are small discriminations about the mean ages and gender ratio among different studies, the results of our study are in agreement with the epidemiological information [11], [12], [13].

Medulloblastomas and ependymomas, usually predominantly solid tumours, are often positioned on the midline in 75% of cases. Medulloblastomas generally progress in the fourth ventricle from the vermis meanwhile ependymomas mostly grow in the fourth ventricle, both resulting in ventricular obstruction and hydrocephalus [13], [16]. Medulloblastomas may hardly expand into the foramina of Magendie or Luschka whereas ependymomas frequently show extension through Magendie and Luschka foramina [13]. By contrast, pilocytic astrocytomas always situate in cerebellar hemisphere and superiorly have mixed appearance of the cystic tumour with mural portion. They slowly evolve and rarely emerge as a solid tumour [13]. Due to typical characteristics of solid tumours, necrosis and haemorrhage appear more common in medulloblastomas and ependymomas than pilocytic astrocytomas [12], [17]. Also, peritumoral oedema presents more generally in patients with medulloblastomas than two other types because medulloblastomas, the most malignant tumour among three types, are graded as 4. As shown in Table 1, our findings of baseline characteristics of three tumour types are absolutely in agreement with previous studies [12], [13], [15], [16], [17].

Typically, medulloblastomas are densely packed cells and hyperchromatic nuclei, which will result in hypointensity to isointense on T1W image [18]. Both hyperintensity on DWI and hypointensity on ADC coexisting with hypointense to isointense T2W are due to high cellularity of the tumour [18], [19]. Among three types, medulloblastomas are highly malignant and hypervascular; hence, the tumours absorb contrast agents vigorously. Absence of enhancement is seldom, which is noticed in only 7.5% of the tumours [12], [20]. Meanwhile ependymomas, generally manifest hypointense T1W, hyperintense T2W, and iso- to hyper-intense FLAIR. On post-contrast enhancement T1W images, tumours generally demonstrate avid enhancement. There are few tumours manifesting little or absence of post-gadolinium enhancement despite being consisted of solid tissue. DWI shows diminished diffusivity within most of ependymomas also due to high cellularity. It is reported that diffusivity of ependymomas is commonly intermediate between that of medulloblastomas and pilocytic astrocytomas [21], [22]. Pilocytic astrocytomas typically appear as a predominant cystic tumour with mural nodule. The cysts of pilocytic astrocytomas are commonly hypointense on T1W and hyperintense on T2W; and FLAIR. In few cases, tumours show hyperintensity on T1W and FLAIR when fluid is highly proteinaceous. Unrestricted diffusion is a typical feature of pilocytic astrocytomas [23], [24]. Tumours mainly show mixed enhancement because of central cysts without absorbing contrast agents, while the mural portions tend to enhance homogenously and noticeably [12]. As shown in Table 2, our MRI findings are completely in line with these studies [12], [18], [19], [20], [21], [22], [23], [24].

In some previous studies, the findings showed that the two most frequent symptoms were headache and vomiting. Also, hydrocephalus was observed in 78-86.7% of the patients [4], [25]. In this present study, two dominant symptoms were also headache and vomiting, and hydrocephalus appeared in 88.7% of patients. The two most common locations of tumours were fourth ventricle and vermis along with the means of three-dimension diameters over 4.5 cm producing intracranial hypertension, ventricular obstruction, and dilated ventricle resulting in these clinical symptoms. Hence, our findings are in agreement with these studies [4], [25].

Four parameters related to the treatment (surgical time, estimated blood loss volume, intensive care unit time, and total hospital admission time) were not generally significantly different. Medulloblastomas and ependymomas are predominantly solid, but pilocytic astrocytomas are principally cystic. Thus, the elimination of medulloblastomas and ependymomas will be more complicated than that of pilocytic astrocytomas. Nevertheless, in this present study, the means of three-dimension diameters of pilocytic astrocytomas were over 5 cm and higher than those of medulloblastomas. In a previous study, the findings showed that brain tumours with a diameter of at least 5cm are considered as giant brain tumour which generates difficulties during the surgery [25]. Thus, there are pros and cons in performing surgery to eradicate the medulloblastomas, ependymomas and pilocytic astrocytomas in this present study leading to

generally insignificant differences among those parameters. Nevertheless, Post-Hoc test revealed that total hospital admission time and intensive care unit time of patients with pilocytic astrocytomas were significantly shorter than those of patients with medulloblastomas. This difference is mainly due to medulloblastomas classified as grade-4 more malignant than pilocytic astrocytomas regarded as grade-1 the most benign tumour amongst three tumour types [13], [15] (Table 3).

Table 3: Postoperative characteristics

Postoperative parameters	Overall n = 62	Medulloblastoma n = 27	Ependymoma n = 20	Pilocytic astrocytoma n = 15	p
Surgical time (hour)	5.0 ± 1.1 (3-7)	5.07 ± 1.11 (3-7)	5.25 ± 1.07 (4-7)	4.47 ± 1.06 (3-6)	0.099
Blood loss volume (ml)	267.1 ± 173.8 (50-1000)	284.82 ± 193.00 (80-1000)	277.00 ± 152.90 (50-500)	222.00 ± 166.83 (50-700)	0.515
Intensive care unit time (day)	3.0 ± 1.6 (1-9)	3.29 ± 1.59 (2-8)	3.15 ± 1.76 (2-9)	2.67 ± 1.03 (1-5)	0.108
Hospital admission time (day)	41.3 ± 22.9 (11-136)	44.96 ± 17.54 (19-98)	44.80 ± 32.13 (11-136)	30.20 ± 12.13 (13-51)	0.096

In this present study, FH diameter had a positive correlation with estimated blood loss and surgical time. The tumours were predominantly located in the fourth ventricle and vermis (80.6%). Anatomically, the fourth ventricle is rather loose at the centre but very narrow to the above Sylvius aqueduct and below central canal of spinal cord. Therefore, the eradication of tumour tissues at the centre of fourth ventricle will be faster and more efficient than tissue nearby sophisticated structures like Sylvius aqueduct and the top of central canal of spinal cord. It is clear that the higher the diameters are, the bigger the tumours are and surgery of bigger tumours will take more time to complete than smaller tumours. We also noticed a positive correlation between surgical time and estimated blood loss. In addition, when the surgical time gets longer to eradicate as much tumour tissue as possible, the blood loss from the collapse of the supplying vascularity of tumour will enhance. In this study, tumors with strong enhancement reflected that perfusion of tumors is significantly effective. Thus, these results are appropriate.

There are some limitations in this present study. Firstly, it is a retrospective design with a small population size; therefore, we do not have abundant and variant findings. Secondly, due to the limitation of innovatively quantified workstation, it is inclined to qualitative research. Thirdly, we just concentrated on three common types of posterior fossa brain tumours in children. Further studies should be as a prospective design with larger sample size. In addition, we also suggest that further studies will introduce quantitative parameters for more objective findings. Future studies also need to focus more on other types of brain tumours to produce plentiful knowledge for clinicians.

In conclusion, MRI plays a crucial role in demonstrating the features of these tumours for appropriate diagnosis and treatment planning. In practice, based on MRI, each tumour has typical MRI features to help clinician discriminate depended on baseline characteristics and MRI characteristics. Among these tumour types, medulloblastomas are problematic brain tumours and the clinicians should take into consideration in cases of larger feet-to-head diameter of tumour to ensure the efficacy and safety surgery for patients.

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References

1. Nguyen QM, Nguyen HC, Parkin DM. Cancer incidence in Ho Chi Minh City, Viet Nam, 1995-1996. Int J Cancer. 1998; 76(4):472-9. https://doi.org/10.1002/(SICI)1097-0215(19980518)76:4<472::AID-IJC5>3.0.CO;2-O

2. Nguyen QM, Nguyen HC, Kramarova E, Parkin DM. Incidence of childhood cancer in Ho Chi Minh City, Vietnam, 1995-97. Paediatr Perinat Epidemiol. 2000; 14(3):240-7. https://doi.org/10.1046/j.1365-3016.2000.00272.x PMid:10949216

3. Chang YW, Yoon HK, Shin HJ, Roh HG, Cho JM. MR imaging of glioblastoma in children: usefulness of diffusion/perfusion-weighted MRI and MR spectroscopy. Pediatr Radiol. 2003; 33(12):836-42. https://doi.org/10.1007/s00247-003-0968-8 PMid:14564423

4. Dorner L, Fritsch MJ, Stark AM, Mehdorn HM. Posterior fossa tumors in children: how long does it take to establish the diagnosis? Childs Nerv Syst. 2007; 23(8):887-90. https://doi.org/10.1007/s00381-007-0323-8 PMid:17429658

5. Ostrom QT, Gittleman H, Xu J, Kromer C, Wolinsky Y, Kruchko C, et al. CBTRUS Statistical Report: Primary Brain and Other Central Nervous System Tumors Diagnosed in the United States in 2009-2013. Neuro Oncol. 2016; 18(suppl_5):v1-v75. https://doi.org/10.1093/neuonc/now207 PMid:28475809

6. Ostrom QT, de Blank PM, Kruchko C, Petersen CM, Liao P, Finlay JL, et al. Alex's Lemonade Stand Foundation Infant and Childhood Primary Brain and Central Nervous System Tumors Diagnosed in the United States in 2007-2011. Neuro Oncol. 2015; 16 Suppl 10:x1-x36. https://doi.org/10.1093/neuonc/nou327 PMid:25542864 PMCid:PMC4277295

7. Guerreiro Stucklin AS, Grotzer MA. Cerebellar tumors. Handb Clin Neurol. 2018; 155:289-99. https://doi.org/10.1016/B978-0-444-64189-2.00019-6 PMid:29891066

8. Cuellar-Baena S, Morales JM, Martinetto H, Calvar J, Sevlever G, Castellano G, et al. Comparative metabolic profiling of paediatric ependymoma, medulloblastoma and pilocytic astrocytoma. Int J Mol Med. 2010; 26(6):941-8. https://doi.org/10.3892/ijmm_00000546 PMid:21042791

9. Kiet H. State and future of radiology and nuclear medicine in Vietnam. Biomed Imaging Interv J. 2009; 5(4):e34. https://doi.org/10.2349/biij.5.4.e34 PMid:21610998 PMCid:PMC3097725

10. Trung le X, Long le X, Tu N, Long NT, Nga NT, Son TV, et al. Brain tumours in Ho Chi Minh City. J Clin Neurosci. 1998; 5(4):421-2. https://doi.org/10.1016/S0967-5868(98)90276-4

11. Panigrahy A, Krieger MD, Gonzalez-Gomez I, Liu X, McComb JG, Finlay JL, et al. Quantitative short echo time 1H-MR spectroscopy of untreated pediatric brain tumors: preoperative diagnosis and characterization. AJNR Am J Neuroradiol. 2006; 27(3):560-72.

12. Poretti A, Meoded A, Huisman TA. Neuroimaging of pediatric posterior fossa tumors including review of the literature. J Magn Reson Imaging. 2012; 35(1):32-47. https://doi.org/10.1002/jmri.22722 PMid:21989968

13. Koob M, Girard N. Cerebral tumors: specific features in children. Diagn Interv Imaging. 2014; 95(10):965-83. https://doi.org/10.1016/j.diii.2014.06.017 PMid:25150727

14. Plaza MJ, Borja MJ, Altman N, Saigal G. Conventional and advanced MRI features of pediatric intracranial tumors: posterior fossa and suprasellar tumors. AJR Am J Roentgenol. 2013; 200(5):1115-24. https://doi.org/10.2214/AJR.12.9725 PMid:23617498

15. Choudhri AF, Siddiqui A, Klimo P, Jr. Pediatric Cerebellar Tumors: Emerging Imaging Techniques and Advances in Understanding of Genetic Features. Magn Reson Imaging Clin N Am. 2016; 24(4):811-21. https://doi.org/10.1016/j.mric.2016.07.006 PMid:27742118

16. Sumer-Turanligil NC, Cetin EO, Uyanikgil Y. A contemporary review of molecular candidates for the development and treatment of childhood medulloblastoma. Childs Nerv Syst. 2013; 29(3):381-8. https://doi.org/10.1007/s00381-012-2014-3 PMid:23292496

17. Rasalkar DD, Chu WC, Paunipagar BK, Cheng FW, Li CK. Paediatric intra-axial posterior fossa tumours: pictorial review. Postgrad Med J. 2013; 89(1047):39-46. https://doi.org/10.1136/postgradmedj-2011-130075 PMid:22977284

18. Koeller KK, Rushing EJ. From the archives of the AFIP: medulloblastoma: a comprehensive review with radiologic-pathologic correlation. Radiographics. 2003; 23(6):1613-37. https://doi.org/10.1148/rg.236035168 PMid:14615567

19. Meyers SP, Kemp SS, Tarr RW. MR imaging features of medulloblastomas. AJR Am J Roentgenol. 1992; 158(4):859-65. https://doi.org/10.2214/ajr.158.4.1546606 PMid:1546606

20. Nelson M, Diebler C, Forbes WS. Paediatric medulloblastoma: atypical CT features at presentation in the SIOP II trial. Neuroradiology. 1991; 33(2):140-2. https://doi.org/10.1007/BF00588252 PMid:2046898

21. Yuh EL, Barkovich AJ, Gupta N. Imaging of ependymomas: MRI and CT. Childs Nerv Syst. 2009; 25(10):1203-13. https://doi.org/10.1007/s00381-009-0878-7 PMid:19360419 PMCid:PMC2744772

22. Rumboldt Z, Camacho DL, Lake D, Welsh CT, Castillo M. Apparent diffusion coefficients for differentiation of cerebellar tumors in children. AJNR Am J Neuroradiol. 2006; 27(6):1362-9.

23. D'Arco F, Khan F, Mankad K, Ganau M, Caro-Dominguez P, Bisdas S. Differential diagnosis of posterior fossa tumours in children: new insights. Pediatr Radiol. 2018; 48(13):1955-63. https://doi.org/10.1007/s00247-018-4224-7 PMid:30120502

24. Chourmouzi D, Papadopoulou E, Konstantinidis M, Syrris V, Kouskouras K, Haritanti A, et al. Manifestations of pilocytic astrocytoma: a pictorial review. Insights Imaging. 2014; 5(3):387-402. https://doi.org/10.1007/s13244-014-0328-2 PMid:24789122 PMCid:PMC4035491

25. Guo A, Suresh V, Liu X, Guo F. Clinicopathological features and microsurgical outcomes for giant pediatric intracranial tumor in 60 consecutive cases. Childs Nerv Syst. 2017; 33(3):447-55. https://doi.org/10.1007/s00381-017-3341-1 PMid:28180935