

Spectrum of intracranial incidental findings on pediatric brain magnetic resonance imaging: What clinician should know?

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Abstract

Intracranial incidental findings on magnetic resonance imaging (MRI) of the brain continue to generate interest in healthy control, research, and clinical subjects. However, in clinical practice, the discovery of incidental findings acts as a "distractor". This review is based on existing heterogeneous reports, their clinical implications, and how the results of incidental findings influence clinical management. This draws attention to the followings: (1) the prevalence of clinically significant incidental findings is low; (2) there is a lack of a systematic approach to classification; and discusses (3) how to deal with the detected incidental findings based a proposed common clinical profile. Individualized neurological care requires an active discussion regarding the need for neuroimaging. Clinical significance of incidental findings should be decided based on lesion's neuroradiologic characteristics in the given clinical context. Available evidence suggests that the outcome of an incidentally found "serious lesion in children" is excellent. Future studies of intracranial incidental findings on pediatric brain MRI should be focused on a homogeneous population. The study should address this clinical knowledge based review powered by the statistical analyses.

Key words: Intracranial incidental finding; Magnetic resonance imaging; Children; Common clinical profile; Seizure; Headache; Developmental delay

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Core tip: The magnetic resonance imaging of the brain in children frequently reveals incidental findings. There is paucity in the literature, how to deal with such findings in clinical practice. This review based on existing heterogeneous reports reveals that the prevalence of clinically significant incidental findings is low and discusses options in the management of incidental findings in children.

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INTRODUCTION

Magnetic resonance imaging (MRI) of the brain is the most commonly performed investigation in the practice of pediatric neurology. During a clinical evaluation, an unexpected finding on brain MRI is a common occurrence. This heightens parental anxiety and generates explanatory discrepancies amongst physicians. Discovery of such findings on neuroimaging is not unique or limited to pediatric brain MRI. Rather, it has been reported in several other conditions such as abdominal and pelvic computerized tomography (CT) and MRI^[1] or in asymptomatic ankles^[2]. Additionally, these findings have been described in asymptomatic healthy volunteer adults^[3], young adults in the community, and in clinic-based subjects^[4].

In clinical practice, MRI of the brain is performed for a variety of indications. Infrequently, findings like pituitary adenoma, lesions of the pineal gland, or central nervous system malignancy are discovered, which have serious implications.

Authors present the evidence-based reports of the current body of knowledge regarding such findings, their clinical implications, and how these findings translate to neurologic management, and discuss a common profile to aid in the clinical management of incidental finding.

METHODOLOGY: LITERATURE SEARCH AND THE RESULTS

In November 2014, we searched Ovid MEDLINE and PubMed databases for reports on the use of brain MRI in children aged 18 years and under. We supplemented the electronic searches with surveillance of electronic tables of contents in neurological journals and by hand searching the bibliographies of pertinent articles. Two authors (Gupta SN and White AC) read

the title and abstract of every study identified by the electronic searches. We critically appraised the full text of potentially eligible studies. Two authors extracted data on study design, population characteristics, and MRI parameters from each study.

Several prospective and retrospective studies have reported incidental findings in pediatric patients. The MRIs of the brain were carried out as an investigatory step in children presenting within various disciplines of pediatric medicine. The summary of identified studies is provided in the Table 1^[5-22].

TERMINOLOGY

The word "incidental or unexpected" generally applies when an identified brain lesion on neuroimaging would have not been predicated by clinicians. This definition can be questioned by some in specific clinical situation. Because the discovery of such lesions in the majority of children does not alter the management, some authors have described them as "benign findings", Schwedt *et al*^[8], 2006.

Multiple terminology have been used to indicate white matter lesions such as periventricular malacia, periventricular white matter changes, white-matter hyperintensity, non-specific white matter abnormalities, white matter signal abnormality, and focal white matter lesion. In the exception to periventricular malacia, the question is if the rest of these terms are the same or of different pathologies. Clinicians have been charged with the task of determining whether or not these definitions are synonymous.

CLASSIFICATION

Intracranial incidental findings are inconsistently classified. The most findings being classified based upon their clinical significance, the type of lesion, normal variant vs abnormal finding, and the urgency for the referral.

Jordan *et al*^[21], 2010, based on the need for referral, classified incidental finding into four categories: No referral, routine referral, urgent referral, or immediate referral. Graf *et al*^[7], 2010 categorized neuroimaging results as normal, remarkable without clinical action, remarkable with clinical follow-up action, and abnormal. Bryan *et al*^[23], 1994 used a very different classification, but a similar method which is used to classify the Cardiovascular Health Study in adults.

Yilmaz *et al*^[5], 2014 classified incidental findings in five categories as follows: (1) cerebral abnormalities relevant to headache such as a growing tumor or hydrocephalus; (2) incidental cerebral abnormalities with potential clinical significance such as Chiari type I malformations, arachnoid cysts, cysts of pineal gland, and inflammatory lesions; (3) incidental cerebral abnormalities without clinical significance such as white matter hyperintensity, periventricular leukomalacia,

Table 1 Summarizes the reports of intracranial incidental findings in children on brain magnetic resonance imaging^[5-22]

Ref.	Country	Study objective /conclusion
Yilmaz <i>et al</i> ^[5]	Turkey	To evaluate clinical significance of MRI abnormality in children with headache/ Despite the high rate of IFs, the yield is non-contributory to diagnosis and therapy
Bayram <i>et al</i> ^[6]	Turkey	To describe the prevalence of WML detected on MRI in children with headaches/ Non-specific WML may be seen in children with headache. In the absence of benefit, repeated MRI studies are unwarranted. It should be tailored according to clinical course
Graf <i>et al</i> ^[7]	United States	Studied the frequency and consequences of IFs on non-acute pediatric headache/ The frequency and types of all IFs were generally comparable to previous studies
Schwedt <i>et al</i> ^[8]	United States	To study the frequency of “benign” abnormalities in children with headache, compare it with the frequency of MRI findings that dictate a change in patient management/ About 20% children with headache have benign findings that do not result in a change in management which rarely occurred in 1.2% of children in this study
Koirala ^[9]	Nepal	To evaluate the yield of MRI findings in patients with seizure/ The majority of abnormalities on MRI included hippocampal sclerosis and T2 hyperintensity
Kalnin <i>et al</i> ^[10]	United States	To characterize IFs association with seizure onset and to standardize a classification system/ The MRI and a standardized scoring system demonstrated a higher rate of IFs than previously reported. MRI parameters need to expand the definition of significant IFs
Gupta <i>et al</i> ^[11]	United States	To test the hypothesis that children with developmental delay are more likely to have incidental findings than are the children with normal development status/ Authors reported a higher prevalence of IFs in children with developmental delay as compared with those with normal development status
Seki <i>et al</i> ^[12]	Japan	To report prevalence of IFs in healthy children and to suggest an ethical and practical management protocol/ The prevalence of IFs was high but those requiring further MRI was low. Evaluating equivocal findings was the most difficult part of IFs management
Gupta <i>et al</i> ^[13]	United States	To elucidate the prevalence of incidental findings in a general pediatric neurology practice/ Authors reported a high prevalence of and a low rate of referrals in comparison to previous studies. This study may help guide management decisions and discussions
Potchen <i>et al</i> ^[14]	Malawi	To collect normative magnetic resonance imaging data for clinical and research applications/ Incidental brain magnetic resonance abnormalities are common in Malawian children
Kim <i>et al</i> ^[15]	United States	To elucidate the prevalence of incidental findings in a healthy pediatric population/ Frequency of important IFs was not high. But, awareness of neurologic status, the presence and variety of IFs are of vital importance for research and welfare of the child
Oh <i>et al</i> ^[16]	South Korea	Incidental findings in pediatric specialty clinic other than neurology To investigated the clinical characteristics of children in whom Rathke’s cleft cysts were incidentally discovered and the treatment response with endocrinopathy/ Rathke’s cleft cysts less than 20 mm expressing cystic intensity can be treated medically
Rachmiel <i>et al</i> ^[17]	Canada	To assess IFs in children with congenital hypothyroidism compared to 38 healthy controls/ Both groups had a similar incidence of structural abnormalities. There was no association between those findings and neurocognitive function
Whitehead <i>et al</i> ^[18]	United States	The prevalence of pineal cysts in children who have had high-resolution 3T brain MRI/ Characteristic-appearing pineal cysts are benign findings. In lack of no referable comprehensive symptoms, no follow-up is required
Mogensen <i>et al</i> ^[19]	Denmark	To evaluate the outcome of brain MRI in girls referred with early signs of puberty/ Girls with central precocious puberty should have a brain MRI
Perret <i>et al</i> ^[20]	Switzerland	The prevalence and management options of incidentally found mass lesions at pediatric clinic/ A subgroup of lesions such as tectal glioma and dysembryoplastic neuroepithelial tumor can be monitored conservatively
Jordan <i>et al</i> ^[21]	United States	The prevalence of incidental findings on brain MRI in children with sickle cell disease/ IFs were present in 6.6% patients and a potentially serious or urgent finding was 0.6%

All except four studies: Potchen *et al*^[14], 2013, Rachmiel *et al*^[17], 2013, Koirala^[9], 2011, and Seki *et al*^[12], 2010, were retrospective. The retrospective study by Jordan *et al*^[21], 2010 was carried out as a clinical trial for sickle cell disease. Itoh *et al*^[22], 1994, investigated the evolution of high-signal-intensity abnormality on T2-weighted MR images^[22] which are the expected findings thus it was excluded from this review. WML: White matter lesions; IFs: Incidental findings; MRI: Magnetic resonance imaging.

subtle gliosis, silent brain infarcts or lacune, and brain microbleeds; (4) extra-cerebral abnormalities relevant to headache such as sinusitis, which was considered as the cause of headache if an otolaryngologist made the diagnosis of sinusitis; and (5) incidental extra-cerebral abnormalities such as mucosal thickening or fluid retention in sinuses or mastoid cells.

The inclusion of “normal-variants” is confusing. For example, commonly occurring pineal cysts are an

asymptomatic finding. Thus, this could be considered a normal finding^[24]. But in a symptomatic patient with the same pineal cyst, there may be a true clinical implication^[25,26]. In some patients, a particular finding in the context of clinical presentation after all may not be incidental. Occasionally, certain findings such as arachnoid cyst may be predicted in specific clinical situations^[27,28].

Some of these findings are classified arbitrarily.

Table 2 Clinical demography of intracranial incidental findings on pediatric brain magnetic resonance imaging evaluated at general neurology clinic and at research center^[5-15]

Ref.	Clinical demographics					Girls n (%) with MRI
	Study- setting	Reason for MRI	No. of subject	No. of MRI (%)	Mean age (range) year	
Yilmaz <i>et al</i> ^[5]	Pediatric neurology	Head pain	449	288 (64) ¹	11.2 (NA)	189 (58)
Bayram <i>et al</i> ^[6]			941	527 (61) ²	12.1 (4-16)	NA
Graf <i>et al</i> ^[7]			400	91 (23) ²	10.8 (3-18)	NA
Schwedt <i>et al</i> ^[8]			681	218 (32) ²	12.1 (2-18) ³	126 (52)
Koirala ^[9]	Pediatric and adult neurology	Seizure	36 ^c	36 (100) ³	NA (1-16)	NA
Kalnin <i>et al</i> ^[10]			349	281 (81)	9.7 (6-14)	143 (51)
Gupta <i>et al</i> ^[11]	Pediatric neurology	Developmental delay	2185	771 (35)	7.6 (NA)	433 (56)
Gupta <i>et al</i> ^[13]		General	1618	666 (41)	9.8 (0-21)	280 (42)
Seki <i>et al</i> ^[12]	Research Institute	Healthy children	395	89 (25) ¹	NA (5-8)	53 (44)
Kim <i>et al</i> ^[15]			225	198 (88) ¹	11.2 (1 mo-18)	126 (56)
Potchen <i>et al</i> ^[14]	Research	Community-based	102	68 (71) ¹	12.1 (9-14)	54 (55)

¹The MRI revealing extracranial incidental findings were excluded; ²Children with computerized tomography of the brain were excluded; ³Only pediatric patients are presented in Table. MRI: Magnetic resonance imaging; NA: Not available.

This practice has resulted in a variety of classification systems which lack clarity. There is an obvious need for a uniform classification system.

NEUROIMAGING

MRI acquisition modalities and the parameters utilized in these studies are variable.

Conventional brain MRI

The conventional MRI was usually performed by using 1.5 Tesla magnetic field strengths scanner. MRI parameters varied but conventional short-TR and short-TE, T1-weighted, long-TR and long-TE, T2-weighted, and fast fluid-attenuated inversion recovery-weighted images were performed in majority of patients. Diffusion and perfusion diffusions images were routinely available in North American Practice of Pediatric Neurology/Neuroradiology.

Advance MRI

Diffusion tensor imaging is an application of diffusion weighted imaging which quantifies water diffusion by measuring molecular motion of water within the brain parenchyma. Lately, this modality has been increasingly used in studying the neuroanatomy of the brain^[29]. This technique is useful particularly in the investigation of white matter abnormalities.

Reporting

Official interpretations are provided by different levels of trained and Board Certified Radiologists. A very limited number of MRI studies were reviewed by Board Certified Pediatric Neuroradiologists. The reporting procedure remains subjective.

The reports should distinguish cerebellar ectopia (downward displacement of cerebellar tonsil/s less than 1 cm through foramen magnum) from Chiari type I malformation. In the face of recent genetic and

phenotypic correlation, there has been a retreat from the Dandy Walker "variant", thus it may be useful to just describe the posterior fossa abnormality. Most importantly, in case of serious lesions, the radiologic characteristics particularly the integrity of the blood-brain barrier should be described in detail.

Future studies may reveal the association between a patient's clinical status and the type of finding, while advances in neuroimaging may reveal their significance. Radiologists should report all such findings within the body of the text, in addition to their subjective interpretation.

The clinical demography of intracranial incidental findings is shown in Tables 2 and 3.

PREVALENCE

The prevalence of intracranial incidental findings is shown in Figure 1.

Variability in prevalence, lowest in healthy children (8%) and the highest in a specific neurologic condition can be explained by an increasing burden of a disorder on the brain. This is probably highest in an elderly brain secondary to ischemic injury particularly to white matter. Arguably, some of the white matter changes are expected findings in neurofibromatosis type I.

Despite suggestions that prevalence rate of incidental findings have increased with frequent use of neuroimaging, during the past decade, it has remained stable in children referred for non-acute headache, Graf *et al*^[30], 2008. Of note, an increasing proportion of neuroimaging studies are being ordered by primary care providers.

TYPE AND DISTRIBUTION

Three most common incidental findings

The three most commonly reported intracranial incidental findings on brain MRI in various pediatric settings

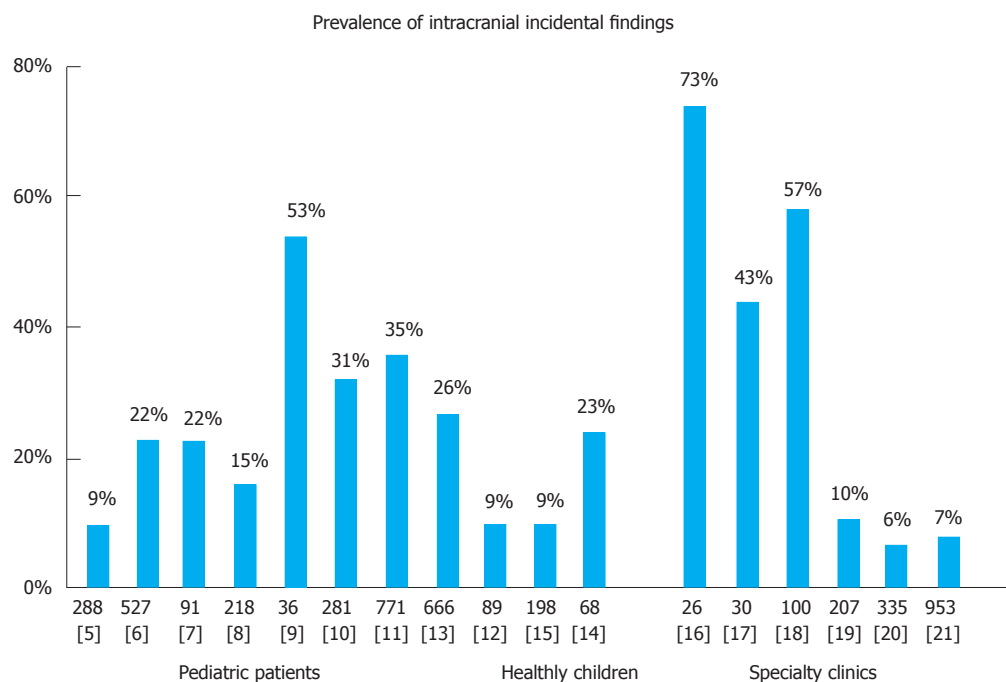


Figure 1 A comparative prevalence of incidental findings on pediatric magnetic resonance imaging of the studies. The numbers above bracket represents number of children in the study; Number in the brackets represents the reference for the study. The subjects in the studies' reference^[5-13] except^[12] on the left were from General Neurology Clinic. The studies^[16-21] on the right were from Specialty Clinics other than neurology. Three studies in middle; ref.^[12,15] were from research in healthy children and the study^[14] was community-based in healthy population.

Table 3 Clinical demography of children with intracranial incidental findings on pediatric brain magnetic resonance imaging studies at pediatric specialty clinic other than neurology^[16-21]

Ref.	Study-setting	Reason for MRI	No. of subject	No. of MRI (%)	Clinical demographics	
					Mean age (range) year	Girls n (%) with MRI
Oh <i>et al</i> ^[16]	Endocrinology	Rathke's cleft cysts	34 ¹	26 (76)	NA (4-18)	17 (65)
Rachmiel <i>et al</i> ^[17]	Endocrinology	Congenital hypothyroidism	68 ²	30 (100)	12.5 (10-15)	16 (55)
Whitehead <i>et al</i> ^[18]	Radiology	Pineal cyst	100	100 (100)	6.8 (1 mo-17)	52 (52)
Mogensen <i>et al</i> ^[19]	Endocrinology	Early puberty	229	207 (100) ³	NA (6-9)	207 (100)
Perret <i>et al</i> ^[20]	Oncology	Primary brain tumor ⁴	335	335 (100)	7.6 (0-18)	132 (39)
Jordan <i>et al</i> ^[21]	Neurology research	Sickle cell disease	953	953 (100)	9.2 (5-15)	460 (48)

¹76% of patient with Rathke's cleft cysts were discovered during evaluations for endocrine disorders; ²This includes 38 healthy boys 11.7 ± 1.7 years; ³22 (11%) patients who had computerized tomography of the brain due to contraindication of MRI are not included in this table; ⁴Central nervous system tumors were identified incidentally. MRI: Magnetic resonance imaging; NA: Not available.

are shown in Table 4. The types of incidental findings on MRI outside of a neurology-setting were generally comparable in these studies.

Incidental "serious brain lesion"

It should be noted that community or general pediatric neurology based studies in healthy subjects have not reported serious or progressively worsening incidentally identified lesions. Nonetheless, serious lesions have been reported by a few studies which are shown in the Table 5^[31].

Morris *et al*^[32] published a meta-analysis, which reviewed 16 studies of subjects within the age range of 1 to 97 years, all of whom had no neurological symptoms. All subjects had brain MRI performed for the purpose of research and for occupational or commercial

screening. The authors reported 135 (0.70%) of 19559 subjects with a neoplastic incidental finding. No age specific prevalence of neoplastic lesion was available for children aged 1 to 9 years. After omitting 34 adults aged 90 to 99, only four 20 year age bands were left for analysis^[32].

Serious lesions can be divided into two groups: (1) ones that are known to get worse, such as a tumor; and (2) those that have the potential for worsening over time, such as pituitary lesions, pineal cysts, or vascular malformations. Such lesions typically manifest with compressive symptoms localized to the adjacent neuroanatomical structure.

Incidental vascular malformations, although uncommon, are frequently asymptomatic, which can greatly complicate the clinical management. It should be noted

Table 4 Lists three most commonly reported intracranial incidental findings on brain magnetic resonance in various pediatric settings^[5-19]

Ref.	Three most common intracranial IFs, <i>n</i> (%)	Comment or serious finding
Yilmaz <i>et al</i> ^[5]	White-matter hyperintensity 14 (4.3)	2 (0.6%) malignant tumor and 1 hydrocephalus, 0.3% IFs were relevant to headache
Bayram <i>et al</i> ^[6]	Old infarcts 4 (1.2), and CM I 3 (0.9)	All patients with IFs had normal development and no seizures or head trauma
Graf <i>et al</i> ^[7]	Supratentorial non-specific WMC 23 (4.4)	Brain stem IFs included Dandy-Walker variant, cerebellar calcification, and tectal plate hyperintensity
Schwedt <i>et al</i> ^[8]	CM I 6 (15), arachnid cysts 6 (15), brain stem parenchymal abnormality, 4 (10)	Discovery of 4 tumors, 4 old infarcts, 3 CM I, and 2 moyamoya required a change in management
Koirala ^[9]	CM I 11 (4.6), nonspecific white matter abnormalities 7 (2.9), venous angiomas and arachnoid cyst each 5 (2.5)	Study focus was IFs in patient with seizure. The lesions were better detected by MRI than computerized tomography
Kalnin <i>et al</i> ^[10]	Hippocampal sclerosis, T2 hyperintense foci in various distributions, both 4 (21) each, cortical atrophy 3 (16)	Temporal lobe lesions were detected 15%, a higher frequency than in previous studies
Gupta <i>et al</i> ^[11]	Ventricular enlargement 143 (51), leukomalacia/gliosis 64 (23), heterotopias and cortical dysplasia 33 (12)	IFs were reported in children with developmental delay as to those with normal development status
Seki <i>et al</i> ^[12]	Variant signal intensity 30 (18), WMC changes 23 (13), and PVL, 10 (6)	Focus of the study was reporting of extracranial IFs in healthy children
Gupta <i>et al</i> ^[13]	Cavum septi pellucidum 6 (15) and Pineal cyst 2 (5), Enlarged perivascular spaces 1 (2.5)	White matter changes were the most common IFs classified under normal-variants
Potchen <i>et al</i> ^[14]	CM I and cerebellar ectopia, 16 (3.5), Arachnoid cysts, 12 (1.8)	Incidental findings were unassociated with age, sex, antenatal problems, or febrile seizures
Kim <i>et al</i> ^[15]	PVW matter changes/gliosis 6 (6), mild diffuse atrophy 4 (4), and Empty sella 3 (3)	IFs were detected on 225 conventional research in a cohort of neurologically healthy children
IFs in pediatric specialty clinics other than neurology	Focal white matter lesion 3 (1.3), arachnoid cyst, frontal venous angioma, and mega cisterna magna, all three 2 (0.9) each	
Oh <i>et al</i> ^[16]	Low signal intensities on T1-WI and high signal intensities on T2-WI 26 (73)	Incidence of hypointensity on T1-WI was higher in patients with Rathke's cleft cysts
Rachmiel <i>et al</i> ^[17]	Prominent VR perivascular spaces, cerebellar ectopia, and abnormalities in sella region all 3 (7.9) each	The comparative study found no IFs association with clinical and cognitive abnormalities
Mogensen <i>et al</i> ^[19]	Arachnoid cysts 5 (9.2), of which one patient had hydrocephalus	Incidental findings were unrelated to early puberty

The study by Whitehead *et al*^[18], 2013, which is not listed in table, because this study was limited to prevalence of pineal cysts in children, who have undergone high-resolution 3-T MRI. CM I: Chiari malformation I; WMC: White matter changes; VR: Virchow-Robin; PVL: Periventricular malacia; PVW: Periventricular white matter changes; IFs: Incidental findings; MRI: Magnetic resonance imaging.

that none of the prospective studies reported any malignant findings as incidental. Potchen *et al*^[14], 2013 prospectively reported granulomas with gliosis as a serious lesion.

Not surprisingly, a significant number of brain tumors were reported from pediatric oncologic-setting, Perret *et al*^[20], 2011. The incidental serious findings in this study included low-grade glioma, craniopharyngioma, ependymoma, choroid plexus papilloma, medulloblastoma, and dysembryoplastic neuroepithelial tumor.

CLINICAL IMPLICATION

Common clinical profile

The common clinical profile of intracranial incidental findings on pediatric brain MRI is shown in the Table 6.

Multiple incidental findings

A 16-year-old girl presented with right facial nerve palsy. She had an unremarkable past medical history. A CT scan of the brain performed due to tingling feeling on the right side of her tongue revealed a partially calcified pineal cyst (Figure 2A). An MRI revealed an enhancing pituitary lesion measuring 13 mm × 10 mm × 10 mm, cerebellar ectopia (Figure 2B), and left maxillary

sinusitis, which is not shown. She had no headaches, visual field defect, hearing difficulty or upper respiratory infection. The question is if her facial nerve palsy is related in any way to neuroimaging findings. The significance of more than one incidental finding is largely unknown.

More than one incidental finding is not uncommon. In the lack of any known implication some of these findings go unreported.

Four out of 18 (22%) studies listed in Table 1 reported more than one incidental finding. An average prevalence of more than one incidental finding in three studies (11, 13, and 17) was 3.8%. The forth study by Bayram *et al*^[6], 2013 reported a very high prevalence (52%) of more than one white matter lesion in children with migraine. In fact the number of patients with more than one lesion exceeded the total number of the patients in this study. Authors' indicated that these were migraine associated changes in the brain^[33].

Managing the MRI results

Incidentally discovered findings should always be considered in the context of the overall clinical impression. One should bear in mind the reason for performing the MRI of the brain. The answer to this

Table 5 Summarizes incidentally found “serious lesions” on pediatric brain magnetic resonance imaging

Ref.	The context in which brain MRI was ordered	Worsening course		Outcome/comment
		Known	Potential	
Yilmaz <i>et al</i> ^[5]	Children mean age 11.2 yr presented for headache evaluation	Malignant brain tumor and hydrocephalus	Chiari I malformation I; Relevant to headache	Tissue type of tumor in study was unspecified
Schwedt <i>et al</i> ^[6]	Children mean age 12.1 yr presented for headache evaluation	Tumors, moyamoya disease, and demyelinating disease	Arteriovenous malformation and intracerebral hemorrhage	Study focus was “benign” imaging abnormalities, no further information for serious lesion other than pineal tumor was available
Kalnin <i>et al</i> ^[10]	Children mean age 9.7 yr presented for the first onset seizure	None	Temporal lobe lesions	Various Epileptic abnormalities ¹ have been associated with pediatric brain MRI
Potchen <i>et al</i> ^[14]	Community-based children mean age 12.1 yr	Granulomas with gliosis	Empty sella and vermian atrophy	Calcified granulomas caused by neurocysticercosis or tuberculosis occurs in the endemic part of the world
Mogensen <i>et al</i> ^[19]	All girls, mean age unavailable, presented for early puberty evaluation to endocrine clinic	Pontine and pineal tumor, and hypothalamic pilocytic astrocytoma	Hydrocephalus, cortical dysplasia, and chiari II malformation	A high frequency a pathological brain findings occurred in 6-8 yr old girls with precocious puberty
² Perret <i>et al</i> ^[20]	Incidentally found mass lesions management in children mean age 7.6 yr in oncology	Low-grade glioma, craniopharyngioma, ependymoma, and CPP	Medulloblastoma and fibrillary astrocytoma	Dysembryoplastic neuroepithelial tumor and tectal glioma can be monitored conservatively
Jordan, <i>et al</i> ^[21]	Children mean age 9.2 yr with sickle cell disease in neurology research	Chiari I malformation with large spinal cord syrinx ³	Possible tectal glioma, Possible tumor <i>vs</i> dysplasia	Amongst 6.6% incidental findings identified, 0.6% children with sickle cell disease had potentially serious or urgent finding

¹Various epileptic abnormalities includes leukomalacia/gliosis, encephalomalacia, any gray matter lesion, mass lesion, hemorrhage, vascular lesion, hippocampal abnormality, ventricular enlargement > 1.5 cm, or prominence of extra-axial fluid spaces > 1.0 cm^[31]; ²Of 335 newly diagnosed central nervous system tumors (CNS), 19 (5.7%) children's CNS tumors were identified incidentally; ³Of note: Chiari I malformation with a small cervical spinal cord syrinx in asymptomatic patients is not uncommon on pediatric brain MRI. CPP: Choroid plexus papilloma; MRI: Magnetic resonance imaging.

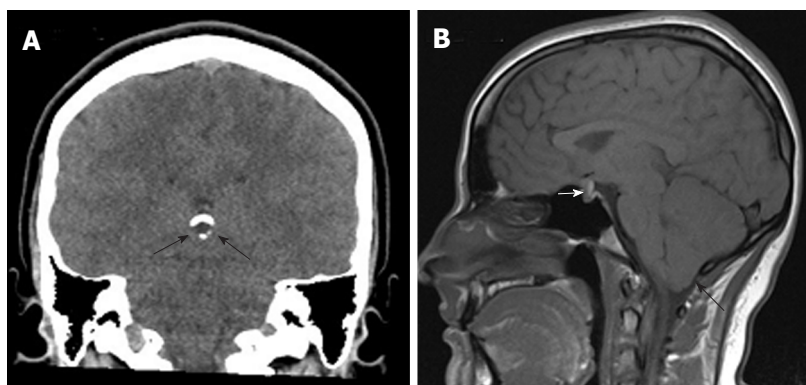


Figure 2 Three out of four incidental findings in a single 16-year-old girl who presented with right facial nerve palsy. The left maxillary sinusitis is not shown. A: Coronal non-contrasted computerized tomography of the brain shows a partially calcified cystic pineal lesion (black arrows); B: A true midline sagittal magnetic resonance image contrast enhancing pituitary mass measuring 13 mm × 10 mm × 10 mm (white arrow) and cerebellar ectopia, 7 mm (black arrow). There was no enhancement of facial nerve in vicinity of the right internal carotid canal.

question can often provide the direction for the next step of clinical management.

The MRI results are best managed at the time of planning for neuroimaging by considering the possibility of an incidental finding. Such preemptive action serves to alleviate parental concern, reduce additional medical care cost, and save physicians' time^[34]. After all, incidental findings are the most common insignificant abnormal findings revealed on pediatric brain MRI.

The parental perceived importance for MRI pro-

cedure is significantly higher than those of physicians. This disassociation of perception may lead to confrontation. This could be avoided by considering the parental concern. The physician's explanation should be based upon the clinical context and what is known about the particular finding. It is only rarely that these findings perpetuate more concerns than the relief^[35].

How did we manage the results of our case? The patient's right facial nerve palsy has no neuroanatomical relation with pituitary lesion, cerebellar ectopia, pineal

Table 6 A proposal for a common clinical profile of intracranial incidental findings on pediatric brain magnetic resonance imaging

Clinical implication	
Discovery of the unexpected incidental findings	Revealing during investigation enhances the patients or parents anxiety. The evidence-based knowledge will provide an additional confidence for the practicing physicians
Type of the incidental findings	Varieties of white matter changes are reported. However, these usually do not initiate a neurologic consultation. Chiari type I malformation, arachnoid cyst, and pineal cyst, all continued to be a common source of concern for some physicians
Distribution of incidental findings	Attention to the distribution of findings is a useful tool in deciding the clinical importance of such findings. A midline lesion particularly in the posterior fossa and hippocampal location is likely to have a serious clinical implication
The clinical context in which MRI was performed	This is probably the single most important step in understating the clinical implication of incidental findings (Table 6). This is particularly important when the child was referred to neurology after revealing the incidental finding on brain MRI

MRI: Magnetic resonance imaging.

cyst, and the left maxillary sinusitis. Of note; sinusitis is the most common extracranial incidental finding on brain MRI. Our patient with facial nerve palsy was treated with a 5 d course of oral steroid. She was referred to an endocrinologist for further evaluation of the pituitary lesion.

How to deal with a “serious incidental finding”?

An MRI revealing serious incidental findings requires close attention. These findings in a pediatric neurology practice remain low (0.3%-3.4%). Presently, there is no consensus regarding the optimal strategy on how to deal with these findings in practice or research^[36].

In general, a midline located lesion with or without surrounding edema or contrast - enhancement needs to be further investigated. Depending upon the nature of the lesion or clinical impression, endocrinological, oncological, or neurosurgical evaluation should be considered.

Author (Gupta SN) preference is to first discuss with the interpreting radiologist and have a plan before delivery of the results to the parents. The necessity and results of such a discussion may vary depending upon the expertise of the clinician or radiologist. To characterize such a lesion systemically, the neuroradiologic differential diagnosis based on the MRI characteristics should be discussed. The presence or absence of perfusion- and diffusion-weighted MRI revealing changes in the diffusion coefficient should be documented^[37]. With the use of intravenous contrast, the status of a blood-brain barrier should be evaluated. In case of non-enhancing lesions such as benign tumors, magnetic resonance spectroscopy^[38] or diffuse tensor imaging may be additional use.

At times an equivocal finding may be perplexing in regards of the management strategy. In such a situation the patient should be followed clinically. Unless neurosurgical intervention is thought to be a realistic probability, the patient with incidental findings of this nature should not receive neurosurgical referral. This will prevent escalating parental anxiety.

Referral and ramification

The majority of children with intracranial incidental findings do not require clinical or neuroimaging follow-

up. Scheduling further appointments merely for incidentally found findings or neuroimaging is likely to increase parental anxiety. Some parents may seek another neurologic consultation. Pituitary lesions, vascular malformations, or tumors have a true future clinical^[39,40] or medico-legal implications. Fortunately, serious lesions in children remain extremely low as compared with adults or the elderly^[41]. Occasionally, they require emergent medical attention and/or subsequent neurosurgical intervention.

Requiring surgical intervention

A very limited number of incidentally found serious lesions include various tumors, which neurosurgical intervention. Non-tumor serious lesions includes Chiari I malformations, syrinx of the cervical spinal cord, and Rathke's cleft cysts. Incidentally discovered lesions requiring neurosurgical interventions and their outcomes are shown in Table 7.

Perret *et al*^[20], 2011, studied 335 children age < 18 years in an oncologic-setting. They reported 19 patients (5.67%) with an incidentally discovered primary brain tumor. Seven patients (2%) underwent immediate surgery; four patients had a low-grade glioma. Craniopharyngioma, ependymoma, and choroid plexus papilloma occurred one in each individual patient. The rest of the 12 (3.5%) children were treated conservatively. Of these 12 conservatively followed, 10 patients (83%) remained stable. The other 2 (17%) underwent surgery because of medulloblastoma and fibrillary astrocytoma progression. The authors of the study concluded that a subgroup of lesions such as tectal glioma and dysembryoplastic neuroepithelial tumor can be monitored conservatively.

Bredlau *et al*^[42] reviewed the clinical course of 244 children over a 10 year period. The study reported 21 (8.6%) incidental brain lesions on MRI. Twelve (4.9%) patients underwent surgical resection of their lesions. Nine out of 10 patients (90%) had a posterior fossa lesion, and three out of 11 (27%) had supratentorial lesions. Authors of the study concluded that incidentally detected serious CNS lesions are small. The outcome for children with such lesions is excellent. They recommended close monitoring with serial MRIs as a safe alternative to immediate biopsy and/or resection

Table 7 Summarizes the neurosurgical intervention and their outcome in children with incidentally discovered serious lesions

Ref.	Incidentally found serious findings	No. of patients	Surgical procedure performed	Outcome
Schwedt <i>et al</i> ^[8]	Chiari type I malformation	3	Surgical decompression	Headache relieved in 2 patients after surgery Neurologic stable
Jordan <i>et al</i> ^[21]	Chiari I malformation with spinal cord syrinx	2	Surgical decompression	
Perret <i>et al</i> ^[20]	Pilocytic astrocytoma	2	Primary subtotal resection	Stable disease
	Craniopharyngioma	1	Primary total resection	Complete remission
	Anaplastic ependymoma	1	Primary total resection, radio-chemotherapy	Complete remission
	Choroid plexus papilloma	1	Primary total resection	Complete remission
	Medulloblastoma	1	Delayed subtotal resection, radio-chemotherapy	Neurologic stable
	Fibrillary astrocytoma	1	Delayed total resection	Complete remission
	Mature teratoma	1	Delayed subtotal resection	Neurologic stable
Mogensen <i>et al</i> ^[19]	Desmoplastic ganglioglioma	1	Primary total resection	Complete remission
	Pilocytic astrocytoma	1	Hypophysectomy	Patients developed pan hypopituitarism after surgery
Yilmaz <i>et al</i> ^[5]	Medulloblastoma	1	Urgent surgery for space occupying lesion	Headache relieved after surgery

Incidental findings; Chiari I malformation studied by Seki *et al*^[12], 2010 and temporal arachnoid cyst with mass effect and cerebellar venous malformation studied by Gupta *et al*^[13], 2008 all three were referred to neurosurgery, but no information regarding outcomes were available.

for select patients^[42]. Of note; the data from adult patients demonstrate that most Rathke's cleft cysts the response to surgery tends to vary based on the endocrinopathology^[43].

MEDICOLEGAL IMPLICATION

Dissatisfaction is an inciting event of litigation in the medical setting. Unlike research or healthy volunteer subjects, no consensus exists on how to handle incidental findings in clinical practice^[44,45].

Claims of inappropriate management, ignorance, or discovery of a serious incidental finding on a later date, all have the potential to result in litigation. The discovery of incidental findings on brain MRI have led to its familiarity and a burden to clinical practice. Clinicians have an obligation of addressing the incidental finding revealed on MRI during the course of clinical evaluation. It is best prevented by pursuing before the availability of actual reports of MRI.

Based on the individual radiologist's perception, the reports of incidental findings on MRI are variable. Hence, many incidental findings might, therefore, remain unreported. Rarely, inconsistencies in reporting may be a cause for litigation.

FUTURE

Neuroimaging with diffuse tensor imaging is likely to unfold the nature of the incidental findings particularly white matter changes. In the future, they are likely to be identified with the use of a high resolution MRI sequences. Use of a standardized scoring system by radiologists will eliminate the individual variability in reporting. This will also be useful in expanding our understating of the incidental findings.

Future review should address the reason for variable prevalence and answer the question if the pattern of incidental finding relates to a specific condition such as headache, seizure, development delay, or any other neurologic condition. Most importantly, this investigation should be addressed by an adequately powered statistical analysis of retrospective or prospective studies in homogeneous populations.

CONCLUSION

The detection of intracranial incidental findings on pediatric brain MRI is of immense importance to daily radiological or clinical practice. The Radiologist should report each and every incidentally discovered finding. Individual variability in reporting of brain MRI findings can be minimized by using unified terminology, describing radiologic characteristics, and by developing a standard radiologic classification system. Because significance of these findings remains unclear, it is important to report them as they are observed, rather than a subjective description.

Intracranial incidental findings are common in both healthy children and children presenting for neurologic evaluation. Prevalence increases with disorders affecting the brain.

Whether or not a reported "incidental finding" should be assigned as clinically significant, is the clinician's prerogative. In uncertainty, the clinical context and course of the problem in question should take precedence. The spectrum of intracranial incidental findings on pediatric brain MRI presented in this review should be the basis for an evidence-based discussion. In addition, the proposed common profile will aid the clinical management of incidentally discovered findings. Most importantly, the management of an incidentally found

serious lesion demands constant surveillance in clinical practice.

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