American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Neuroendocrine Imaging**

Variant 1: **Hypopituitarism.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	8	Multiplanar thin sellar imaging.	None
MRI head without contrast	7	Multiplanar thin sellar imaging.	None
CT head without contrast	4	Indicated if MRI not available or contraindicated.	Low
CT head without and with contrast	4	Indicated if MRI not available or contraindicated.	Low
MRA head	3	Indicated if better visualization of carotid arteries needed.	None
CTA head	2	For surgical planning or vascular detail if MRI and MRA contraindicated.	Low
X-ray tomography skull	1		Min
X-ray sella	1		Min
INV angiography cerebral	1		IP
INV venous sampling	1		IP
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Clinical Condition: **Neuroendocrine Imaging**

Variant 2: **Obesity/eating disorder.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without contrast	4	In carefully selected patients with high clinical likelihood of structural abnormality. Multiplanar thin sellar imaging.	None
MRI head without and with contrast	4	In carefully selected patients with high clinical likelihood of structural abnormality. Multiplanar thin sellar imaging.	None
CT head without contrast	3	Indicated if MRI not available or contraindicated. In selected patients with high clinical likelihood of structural abnormality.	Low
CT head without and with contrast	3	Indicated if MRI not available or contraindicated. In selected patients with high clinical likelihood of structural abnormality.	Low
MRA head	2		None
X-ray sella	1		Min
INV angiography cerebral	1		IP
INV venous sampling	1		IP
X-ray tomography skull	1		Min
CTA head	1		Low
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Clinical Condition: **Neuroendocrine Imaging**

Variant 3: **Hyperthyroidism (high TSH).**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	8	Multiplanar thin sellar imaging.	None
MRI head without contrast	7	Multiplanar thin sellar imaging.	None
CT head without contrast	3	Indicated if MRI not available or contraindicated.	Low
CT head without and with contrast	3	Indicated if MRI not available or contraindicated.	Low
MRA head	3		None
CTA head	2	For surgical planning or vascular detail if MRI and MRA contraindicated.	Low
INV angiography cerebral	1		IP
X-ray tomography skull	1		Min
X-ray sella	1		Min
INV venous sampling	1		IP
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Variant 4: **Cushing's syndrome (high ACTH).**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	8	Multiplanar thin sellar imaging.	None
MRI head without contrast	7	Multiplanar thin sellar imaging.	None
CT head without and with contrast	4	Indicated if MRI not available or contraindicated.	Low
INV venous sampling	4	Indicated if MRI is negative or equivocal.	IP
CT head without contrast	4	Indicated if MRI not available or contraindicated.	Low
MRA head	3	Indicated if better visualization of carotid arteries needed.	None
CTA head	2		Low
X-ray sella	1		Min
INV angiography cerebral	1		IP
X-ray tomography skull	1		Min
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Clinical Condition: **Neuroendocrine Imaging**

Variant 5: **Hyperprolactinemia.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	8	Multiplanar thin sellar imaging.	None
MRI head without contrast	7	Multiplanar thin sellar imaging.	None
CT head without and with contrast	4	Indicated if MRI not available or contraindicated.	Low
CT head without contrast	4	Indicated if MRI not available or contraindicated.	Low
MRA head	3	Indicated if better visualization of carotid arteries needed.	None
CTA head	2	For surgical planning or vascular detail if MRI and MRA contraindicated.	Low
X-ray sella	1		Min
INV venous sampling	1	Indicated in unusual cases in which lateralization is indeterminate.	IP
INV angiography cerebral	1		IP
X-ray tomography skull	1		Min
Rating Scale: 1=Least appropriate, 9=Most appropriate			***Relative Radiation Level**

Variant 6: **Acromegaly/gigantism.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	8	Multiplanar thin sellar imaging.	None
MRI head without contrast	7	Multiplanar thin sellar imaging.	None
CT head without and with contrast	4	Indicated if MRI not available or contraindicated.	Low
CT head without contrast	4	Indicated if MRI not available or contraindicated.	Low
INV venous sampling	3	Indicated in unusual cases in which lateralization is indeterminate.	IP
MRA head	3	Indicated if better visualization of carotid arteries needed.	None
CTA head	2	For surgical planning or vascular detail if MRI and MRA contraindicated.	Low
X-ray sella	1		Min
X-ray tomography skull	1		Min
INV angiography cerebral	1		IP
Rating Scale: 1=Least appropriate, 9=Most appropriate			***Relative Radiation Level**

Clinical Condition: **Neuroendocrine Imaging**

Variant 7: **Dwarfism (proportionate).**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without contrast	7	Multiplanar thin sellar imaging.	None
MRI head without and with contrast	5	Multiplanar thin sellar imaging.	None
CT head without contrast	4	Indicated if MRI not available or contraindicated.	Low
CT head without and with contrast	4	Indicated if MRI not available or contraindicated.	Low
MRA head	2		None
CTA head	2	For surgical planning or vascular detail if MRI and MRA contraindicated.	Low
INV angiography cerebral	1		IP
X-ray tomography skull	1		Min
X-ray sella	1		Min
INV venous sampling	1		IP
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Variant 8: **Diabetes insipidus.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without contrast	7	Multiplanar thin sellar imaging.	None
MRI head without and with contrast	6	Multiplanar thin sellar imaging.	None
MRA head	4		None
CT head without contrast	4	Indicated if MRI not available or contraindicated.	Low
CT head without and with contrast	4	Indicated if MRI not available or contraindicated.	Low
CTA head	2	For surgical planning or vascular detail if MRI and MRA contraindicated.	Low
INV venous sampling	1		IP
X-ray tomography skull	1		Min
INV angiography cerebral	1		IP
X-ray sella	1		Min
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Clinical Condition: **Neuroendocrine Imaging**

Variant 9: **Pituitary apoplexy.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	8	Multiplanar thin sellar imaging.	None
MRI head without contrast	7	Multiplanar thin sellar imaging.	None
CT head without contrast	6		Low
MRA head	4	Indicated if better visualization of carotid arteries needed.	None
CT head without and with contrast	4	Indicated if MRI not available or contraindicated.	Low
CTA head	4		Low
X-ray tomography skull	1		Min
INV venous sampling	1		IP
INV angiography cerebral	1		IP
X-ray sella	1		Min
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Variant 10: **Postoperative sella.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	8	Multiplanar thin sellar imaging.	None
MRI head without contrast	7	Multiplanar thin sellar imaging.	None
CT head without and with contrast	4	CT may be indicated to assess bony anatomy and if MRI is not available or contraindicated.	Low
CT head without contrast	4	CT may be indicated to assess bony anatomy and if MRI is not available or contraindicated.	Low
CTA head	4		Low
MRA head	2		None
X-ray sella	1		Min
X-ray tomography skull	1		Min
INV angiography cerebral	1		IP
INV venous sampling	1		IP
Rating Scale: 1=Least appropriate, 9=Most appropriate			*Relative Radiation Level

Clinical Condition: **Neuroendocrine Imaging**

Variant 11: **Precocious puberty.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with contrast	8	Multiplanar thin sellar imaging.	None
MRI head without contrast	7	Multiplanar thin sellar imaging.	None
CT head without contrast	2		Low
CT head with contrast	2	If MRI not available or contraindicated.	Low
CTA head	2		Low
MRA head	2		None
X-ray sella	1		Min
X-ray tomography skull	1		Min
INV angiography cerebral	1		IP
INV venous sampling	1		IP
Rating Scale: 1=Least appropriate, 9=Most appropriate			***Relative Radiation Level**

Expert Panel on Neurologic Imaging: David J. Seidenwurm, MD[1]; Patricia C. Davis, MD[2]; James A. Brunberg, MD[3]; Robert Louis De La Paz, MD[4]; Pr. Didier Dormont[5]; David B. Hackney, MD[6]; John E. Jordan, MD[7]; John P. Karis, MD[8]; Suresh Kumar Mukherji, MD[9]; Patrick A. Turski, MD[10]; Franz J. Wippold II, MD[11]; Robert D. Zimmerman, MD[12]; Michael W. McDermott, MD[13]; Michael A. Sloan, MD, MS.[14]

Summary of Literature Review

The imaging approach to the hypothalamic pituitary axis is based on specific endocrine testing suggested by clinical signs and symptoms. Endocrine disorders are generally characterized by excess or deficiency of specific hormones. Hormone excess is diagnosed under conditions that would ordinarily suppress hormone secretion. Endocrine deficiencies are diagnosed on the basis of hormone measurements under conditions of stimulation. Specific clinical syndromes of hormonal disorders are determined by the physiologic role of that particular hormone.

The hypothalamic pituitary axis consists of two separate neuroendocrine organs, the anterior pituitary system and the posterior pituitary system. The hormones of the anterior pituitary are thyroid stimulating hormone (TSH), adrenal corticotrophic hormone (ACTH), prolactin (PRL), growth hormone (GH), and the gonadotropins (FSH and LH). These are secreted under the influence of hypothalamic trophic factors, corticotrophin releasing factor (CRF), thyrotropin releasing factor (TRF) and somatostatin- and gonadotropin- releasing hormone (GnRH). Prolactin release is under the control of a dopaminergic circuit. The hypothalamic-releasing hormones are transported to the pituitary gland by the hypophyseal portal system.

The posterior pituitary gland consists of axonal terminations of neurons whose cell bodies are located in the hypothalamus. The principal hormones secreted by these cells are oxytocin and vasopressin or antidiuretic hormone (ADH). The hypothalamus also participates in complex mediation of food intake, temperature regulation, sleep and arousal, memory, thirst, and other autonomic functions.

Structural causes of obesity, anorexia, central hypothermia and hyperthermia, insomnia, and hypersomnia are only very rarely demonstrated in the hypothalamus and pituitary gland. Imaging in patients who present with these symptoms absent other specific neurological or endocrine abnormality is almost always unrewarding. An exception is in children in whom the "diencephalic syndrome" of hypothalamic lesions is relatively common. Also, precocious puberty in children can result from hypothalamic lesions.

Pituitary adenomas are the most common lesions of the pituitary gland. These may secrete prolactin, TSH, GH, ACTH, or gonadotropins. Prolactinomas are the most common and are generally present as microadenomas in premenopausal females with amenorrhea and galactorrhea. Prolactin elevation by itself is nonspecific and may be due to a variety of medical, neurological, or pharmacological causes as well as pituitary adenoma, depending on serum hormone level. In males, prolactinomas may be entirely asymptomatic until visual symptoms occur, due to compression of the chiasm, or they may result in hypogonadotropic hypogonadism with loss of libido and impotence. Growth-hormone-secreting tumors generally present as larger lesions manifesting clinical acromegaly. Because of the gradual onset of deformity, these tumors may be present for many years and grow to substantial size prior to their detection. In a prepubertal individual the growth-hormone-secreting tumor may result in gigantism. TSH- and ACTH-secreting tumors may present at very small size because the impact of their hormone product is usually apparent more rapidly. Gonadotropin-secreting tumors are rare.

Precocious puberty and other neurological symptoms can be produced by hypothalamic lesions such as hamartoma. MRI is generally indicated in all patients with endocrinologically confirmed precocious puberty, especially when rapid progression of development and neurological symptoms are present.

Posterior pituitary dysfunction with loss of antidiuretic hormone results in the clinical syndrome of diabetes insipidus. This may occur as a transient phenomenon after trauma or neurosurgical procedures. The etiology is usually evident, and the phenomenon is frequently transient. Imaging is performed to search for the cause of stalk transsection, which can be a manifestation of numerous sellar or parasellar pathologies, trauma, or congenital. Rarely, the hormone is absent

[1]Principal Author and Panel Chair, Radiological Associates of Sacramento, Sacramento, Calif; [2]Vice-Chair, Northwest Radiology Consultants, Atlanta, Ga; [3]University of California-Davis Medical Center, Sacramento, Calif; [4]Columbia University Medical Center, New York, NY; [5]Hôpital de la Salpêtrière, Assistance-Publique-Hôpitaux de Paris, France; [6]Beth Israel Medical Center, Boston, Mass; [7]Memrad Medical Group, Inc., Long Beach, Calif; [8]SW Neuro-Imaging, Phoenix, Ariz; [9]University of Michigan Health System, Ann Arbor, Mich; [10]University of Wisconsin, Madison, Wis; [11]Mallinckrodt Institute of Radiology, Saint Louis, MO; [12]New York Hospital-Cornell University Medical Center, New York, NY; [13]University of California-San Francisco, San Francisco, Calif, American Association of Neurlogical Surgeons; [14]Carolinas Medical Center, Charlotte, NC, American Academy of Neurology.

Reprint requests to: Department of Quality & Safety, American College of Radiology, 1891 Preston White Drive, Reston, VA 20191-4397.

developmentally. The syndrome of inappropriate ADH is usually due to an extracranial source. Frequently this is a paraneoplastic phenomenon related to small-cell lung carcinoma, though a variety of pulmonary diseases and pharmacological disturbances can result in SIADH.

Other common mass lesions that may affect the neuroendocrine system are germ-line tumors, meningioma, craniopharyngioma, and Rathke's cleft cyst among others. Metastatic lesions may affect the sella. Sarcoid and other inflammatory processes occur in the sellar and suprasellar regions as well. Pituitary apoplexy is a syndrome of headache ophthalmoplegia and visual loss that results from pituitary hemorrhage. In the postpartum period, pituitary infarcts may occur, and hypophysitis is an uncommon disorder resulting in endocrine disturbance and other symptoms.

Classically, plain radiography and pluridirectional x-ray tomography was the mainstay of sellar imaging. Computed tomography (CT) largely replaced these modalities through the seventies and eighties. More recently, magnetic resonance imaging (MRI) has largely supplanted CT. MRI for sellar pathology includes thin-section multiplanar imaging with slice thickness of 3mm or less, often before and after contrast administration. Other techniques that are used for evaluation of this anatomical region are computed tomography angiography (CTA), magnetic resonance angiography (MRA), direct catheter angiography, and petrosal sinus sampling.

Plain radiography and pluridirectional tomography are insensitive and nonspecific imaging modalities for evaluating sellar pathology. Pituitary microadenoma and even small pituitary macroadenomas are frequently associated with a normal sella size. The sella turcica can be enlarged when no neoplasm or mass is present. This is due to pulsations of cerebral spinal fluid (CSF) transmitted through a developmental or acquired dehiscence of the diaphragm sella in the empty sella syndrome. Therefore, these imaging modalities are rarely, if ever, employed productively in the evaluation of endocrine disease.

CT revolutionized evaluation of the sella and suprasellar region. Due to the ability of CT, especially with intravenous contrast, to depict pathology within the unenlarged sella, and its ability to visualize suprasellar pathology noninvasively, this technique facilitates accurate diagnosis of neuroendocrine abnormality. Pituitary microadenomas and macroadenomas are reliably detected. There is, however, difficulty at times in distinguishing the tumor from the optic chiasm, diagnosis of cavernous sinus invasion is difficult, and on occasion, cystic lesions of the suprasellar region may be confused with normal CSF.

Additionally, artifact due to dental amalgam, difficulty in obtaining reliable contrast enhancement, and awkward positioning for direct coronal scanning limit the utility of this imaging modality. In the hands of experienced radiologists this technique can result in excellent diagnostic accuracy, though the examinations are sometimes difficult to interpret despite excellent technique.

MRI provides excellent noninvasive evaluation of the hypothalamus and pituitary gland. It is the only imaging modality that reliably depicts the hypothalamus in a useful fashion. It depicts the anatomy of the pituitary gland, infundibulum, optic chiasm, cavernous sinuses, and neighboring vascular structures accurately and noninvasively.

The addition of gadolinium facilitates diagnosis of microadenoma and increases the confidence with which cavernous sinus invasion can be diagnosed or excluded. The specific bony landmarks may be difficult to demonstrate, but the signal pattern of sphenoid sinus mucosa permits assessment of septa for operative planning. Visualization of vascular structures in the parasellar region or even intrasellar carotid artery loop or aneurysm is crucial in some cases.

Angiography is reserved for those patients in whom vascular pathology is known or suspected on the basis of clinical or radiological findings. Aneurysm is the most important vascular lesion in the parasellar region, but these lesions rarely present as endocrine disorders. Knowledge of vascular anatomy guides surgery. Occasionally, a sellar lesion may grow to displace or encase the carotid arteries or other major intracranial vessels. Interventional neuroradiology procedures can be planned on the basis of CTA, MRA, or catheter angiography.

Petrosal sinus venous sampling is reserved for those cases in which a definite excess of pituitary hormone is present, medical management has failed, sectional imaging is negative or equivocal and surgery is planned. When a significant discrepancy in hormone level, usually ACTH, exists between the vessels studied, tumor localization is very accurate. Complications occur uncommonly in experienced hands.

A significant problem encountered in CT and MRI imaging of the pituitary, particularly when endocrine findings suggest microadenoma, is the false positive examination. Since the endocrine studies confirm the presence of a lesion, and first-line therapy is usually medical, false negative examinations are less problematic once chiasmatic compression has been excluded. Approximately 20% of the population may harbor small incidental nonfunctioning adenomas or cysts. It is

important, therefore, that the probability of disease be high in the target population if a positive MRI is to be relied upon for surgical planning. Additional problems are created by variations in size of the pituitary gland, which occur normally in response to physiological hormonal changes. The gland may enlarge in puberty and pregnancy. Pituitary hyperplasia in hypothyroidism may simulate a pituitary adenoma in some patients. Similar problems arise in imaging the posterior pituitary, since up to 29% of normal subjects do not demonstrate a bright posterior pituitary.

References

1. Argyropoulou M, Perignon F, Brauner R, Brunelle F. Magnetic resonance imaging in the diagnosis of growth hormone deficiency. *J Pediatr* 1992; 120(6):886-891.
2. Bonneville JF, Cattin F, Dietemann JL. Hypothalamic-pituitary region: computed tomography imaging. *Baillieres Clin Endocrinol Metab* 1989; 3(1):35-71.
3. Carr DH, Sandler LM, Joplin GF. Computed tomography of sellar and parasellar lesions. *Clin Radiol* 1984; 35(4):281-286.
4. Chakeres DW, Curtin A, Ford G. Magnetic resonance imaging of pituitary and parasellar abnormalities. *Radiol Clin North Am* 1989; 27(2):265-281.
5. De Herder WW, Lamberts SW. Imaging of pituitary tumours. *Baillieres Clin Endocrinol Metab* 1995; 9(2):367-389.
6. Dietemann JL, Cromero C, Tajahmady T, et al. CT and MRI of suprasellar lesions. *J Neuroradiol* 1992; 19(1):1-22.
7. Donovan JL, Nesbit GM. Distinction of masses involving the sella and suprasellar space: specificity of imaging features. *AJR* 1996; 167(3):597-603.
8. Elster AD. Imaging of the sella: anatomy and pathology. *Semin Ultrasound CT MR* 1993; 14(3):182-194.
9. Escourolle H, Abecassis JP, Bertagna X, et al. Comparison of computerized tomography and magnetic resonance imaging for the examination of the pituitary gland in patients with Cushing's disease. *Clin Endocrinol* 1993; 39(3):307-313.
10. Glick RP, Tiesi JA. Subacute pituitary apoplexy: clinical and magnetic resonance imaging characteristics. *Neurosurgery* 1990; 27(2):214-218.
11. Goldstein SJ, Lee C, Carr WA, Rosenbaum HD, Tibbs PA, Walsh JW. Magnetic resonance imaging of the sella turcica and parasellar region: a clinical-radiographic evaluation with computed tomography. *Surg Neurol* 1986; 26(4):330-337.
12. Guy RL, Benn JJ, Ayers AB, et al. A comparison of CT and MRI in the assessment of the pituitary and parasellar region. *Clin Radiol* 1991; 43(3):156-161.
13. Harrison MJ, Morgello S, Post KD. Epithelial cystic lesions of the sellar and parasellar region: a continuum of ectodermal derivatives? *J Neurosurg* 1994; 80(6):1018-1025.
14. Hershey BL. Suprasellar masses: diagnosis and differential diagnosis. *Semin Ultrasound CT MR* 1993; 14(3):215-231.
15. Hirsch WL Jr, Hryshko FG, Sekhar LN, et al. Comparison of MR imaging, CT, and angiography in the evaluation of the enlarged cavernous sinus. *AJR* 1988; 151(5):1015-1023.
16. Isaacs RS, Donald PJ. Sphenoid and sellar tumors. *Otolaryngol Clin North Am* 1995; 28(6):1191-1229.
17. Jafar JJ, Crowell RM. Parasellar and optic nerve lesions: the neurosurgeon's perspective. *Radiol Clin North Am* 1987; 25(4):877-892.
18. Johnson MR, Hoare RD, Cox T, et al. The evaluation of patients with a suspected pituitary microadenoma: computer tomography compared to magnetic resonance imaging. *Clin Endocrinol* 1992; 36(4):335-338.
19. Kasperlik-Zaluska A, Walecki J, Brzezinski J, et al. MRI versus CT in the diagnosis of Nelson's syndrome. *Eur Radiol* 1997; 7(1):106-109.
20. L'Huillier F, Combes C, Martin N, Leclerc X, Pruvo JP, Gaston A. MRI in the diagnosis of so-called pituitary apoplexy: seven cases. *J Neuroradiol* 1989; 16(3):221-237.
21. Levine PA, Paling MR, Black WC, Cantrell RW. MRI vs. high-resolution CT scanning: evaluation of the anterior skull base. *Otolaryngol Head Neck Surg* 1987; 96(3):260-267.
22. Lieberman S. Diseases of the pituitary. In: Fishman MC, et al, eds. *Medicine*. Philadelphia, Pa: Lippincott-Raven Publishers; 1996:165.
23. Lopez J, Barcelo B, Lucas T, et al. Petrosal sinus sampling for diagnosis of Cushing's disease: evidence of false negative results. *Clin Endocrinol (Oxf)* 1996; 45(2):147-156.
24. Lundin P, Bergstrom K, Thuomas KA, Lundberg PO, Muhr C. Comparison of MR imaging and CT in pituitary macroadenomas. *Acta Radiol* 1991; 32(3):189-196.
25. Macpherson P, Teasdale E, Hadley DM, Teasdale G. Invasive v non-invasive assessment of the carotid arteries prior to trans-sphenoidal surgery. *Neuroradiology* 1987; 29(5):457-461.
26. Macpherson P, Hadley DM, Teasdale E, Teasdale G. Pituitary microadenomas. Does gadolinium enhance their demonstration? *Neuroradiology* 1989; 31(4):293-298.
27. Maghnie M, Triulzi F, Larizza D, et al. Hypothalamic-pituitary dwarfism: comparison between MR imaging and CT findings. *Pediatr Radiol* 1990; 20(4):229-235.
28. Doraiswamy PM, Krishnan KR, Figiel GS, et al. A brain magnetic resonance imaging study of pituitary gland morphology in anorexia nervosa and bulimia. *Biol Psychiatry* 1990; 28(2):110-116.
29. Naheedy MH, Haag JR, Azar-Kia B, Mafee MF, Elias DA. MRI and CT of sellar and parasellar disorders. *Radiol Clin North Am* 1987; 25(4):819-847.
30. Nichols DA, Laws ER Jr, Houser OW, Abboud CF. Comparison of magnetic resonance imaging and computed tomography in the preoperative evaluation of pituitary adenomas. *Neurosurgery* 1988; 22(2):380-385.
31. Pellini C, di Natale B, De Angelis R, et al. Growth hormone deficiency in children: role of magnetic resonance imaging in assessing aetiopathogenesis and prognosis in idiopathic hypopituitarism. *Eur J Pediatr* 1990; 149(8):536-541.
32. Rodriguez O, Mateos B, de la Pedraja R, et al. Postoperative follow-up of pituitary adenomas after trans-sphenoidal resection: MRI and clinical correlation. *Neuroradiology* 1996; 38(8):747-754.
33. Sato N, Endo K, Ishizaka H, Matsumoto M. Serial MR intensity changes of the posterior pituitary in a patient with anorexia nervosa, high serum ADH, and oliguria. *J Comput Assist Tomogr* 1993; 17(4):648-650.
34. Terano T, Seya A, Tamura Y, Yoshida S, Hirayama T. Characteristics of the pituitary gland in elderly subjects from magnetic resonance images: relationship to pituitary hormone secretion. *Clin Endocrinol (Oxf)* 1996; 45(3): 273-279.
35. Tripathi S, Ammini AC, Bhatia R, et al. Cushing's disease: pituitary imaging. *Australas Radiol* 1994; 38(3):183-186.
36. Zucchini S, di Natale B, Ambrosetto P, De Angelis R, Cacciari E, Chiumello G. Role of magnetic resonance imaging in hypothalamic-pituitary disorders. *Horm Res* 1995; 44(Suppl3):8-14.
37. Debeneix C, Bourgeois M, Trivin C, Sainte-Rose C, Brauner R. Hypothalamic hamartoma: comparison of clinical presentation and magnetic resonance images. *Horm Res* 2001; 56(1-2):12-18.
38. Grunt JA, Midyett LK, Simon SD, Lowe L. When should cranial magnetic resonance imaging be used in girls with early sexual development? *J Pediatr Endocrinol Metab* 2004; 17(5):775-780.
39. Sade B, Mohr G, Vezina JL. Distortion of normal pituitary structures in sellar pathologies on MRI. *Can J Neurol Sci* 2004; 31(4):467-473.
40. Ng SM, Kumar Y, Cody D, Smith CS, Didi M. Cranial MRI scans are indicated in all girls with central precocious puberty. *Arch Dis Child* 2003; 88(5):414-418.
41. Freeman JL, Coleman LT, Wellard RM, et al. MR imaging and spectroscopic study of epileptogenic hypothalamic hamartomas: analysis of 72 cases. *AJNR* 2004; 25(3):450-462.

42. Bozzola M, Mengarda F, Sartirana P, Tato L, Chaussain JL. Long-term follow-up evaluation of magnetic resonance imaging in the prognosis of permanent GH deficiency. *Eur J Endocrinol* 2000; 143(4):493-496.
43. Pisaneschi M, Kapoor G. Imaging the sella and parasellar region. *Neuroimaging Clin N Am* 2005; 15(1):203-219. Review.
44. Longui CA, Rocha AJ, Menezes DM, et al. Fast acquisition sagittal T1 magnetic resonance imaging (FAST1-MRI): a new imaging approach for the diagnosis of growth hormone deficiency. *J Pediatr Endocrinol Metab* 2004; 17(8):1111-1114.