American College of Radiology
ACR Appropriateness Criteria®

Clinical Condition: **Neuroendocrine Imaging**

Variant 1: **Hypopituitarism.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with IV contrast	8	Multiplanar thin sellar imaging.	O
MRI head without IV contrast	7	Multiplanar thin sellar imaging.	O
CT head with IV contrast	5	Indicated if MRI is not available or contraindicated.	☢☢☢
CT head without IV contrast	4	Indicated if MRI is not available or contraindicated.	☢☢☢
CT head without and with IV contrast	4	Indicated if MRI is not available or contraindicated.	☢☢☢
MRA head without IV contrast	3	May be useful if vascular pathology is known or suspected.	O
MRA head without and with IV contrast	3	May be useful if vascular pathology is known or suspected.	O
CTA head with IV contrast	2	For surgical planning or vascular detail if MRI and MRA are contraindicated.	☢☢☢
X-ray tomography head	1		☢
X-ray sella	1		☢
Arteriography cerebral	1		☢☢☢
Venous sampling petrosal sinus	1		Varies

Rating Scale: **1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate** ***Relative Radiation Level**

Clinical Condition: **Neuroendocrine Imaging**

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

Radiologic Procedure	Rating	Comments	RRL*
CT head with IV contrast	5	Indicated if MRI is not available or contraindicated. In selected patients with high clinical likelihood of structural abnormality.	☢ ☢ ☢
MRI head without IV contrast	4	In carefully selected patients with high clinical likelihood of structural abnormality. Multiplanar thin sellar imaging.	O
MRI head without and with IV contrast	4	In carefully selected patients with high clinical likelihood of structural abnormality. Multiplanar thin sellar imaging.	O
CT head without IV contrast	3	Indicated if MRI is not available or contraindicated. In selected patients with high clinical likelihood of structural abnormality.	☢ ☢ ☢
CT head without and with IV contrast	3	Indicated if MRI is not available or contraindicated. In selected patients with high clinical likelihood of structural abnormality.	☢ ☢ ☢
MRA head without IV contrast	3	May be useful if vascular pathology is known or suspected.	O
MRA head without and with IV contrast	3	May be useful if vascular pathology is known or suspected.	O
X-ray tomography head	1		☢
X-ray sella	1		☢
CTA head with IV contrast	1		☢ ☢ ☢
Arteriography cerebral	1		☢ ☢ ☢
Venous sampling petrosal sinus	1		Varies
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Neuroendocrine Imaging**

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

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with IV contrast	8	Multiplanar thin sellar imaging.	O
MRI head without IV contrast	7	Multiplanar thin sellar imaging.	O
CT head with IV contrast	5	Indicated if MRI is not available or contraindicated.	☢☢☢
CT head without IV contrast	3	Indicated if MRI is not available or contraindicated.	☢☢☢
CT head without and with IV contrast	3	Indicated if MRI is not available or contraindicated.	☢☢☢
MRA head without IV contrast	3	May be useful if vascular pathology is known or suspected.	O
MRA head without and with IV contrast	3	May be useful if vascular pathology is known or suspected.	O
CTA head with IV contrast	2	For surgical planning or vascular detail if MRI and MRA are contraindicated.	☢☢☢
X-ray tomography head	1		☢
X-ray sella	1		☢
Arteriography cerebral	1		☢☢☢
Venous sampling petrosal sinus	1		Varies
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Neuroendocrine Imaging**

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

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with IV contrast	8	Multiplanar thin sellar imaging.	O
MRI head without IV contrast	7	Multiplanar thin sellar imaging.	O
CT head with IV contrast	5	Indicated if MRI is not available or contraindicated.	☢☢☢
CT head without and with IV contrast	4	Indicated if MRI is not available or contraindicated.	☢☢☢
Venous sampling petrosal sinus	4	Indicated if MRI is negative or equivocal.	Varies
CT head without IV contrast	4	Indicated if MRI is not available or contraindicated.	☢☢☢
MRA head without IV contrast	3	May be useful if vascular pathology is known or suspected.	O
MRA head without and with IV contrast	3	May be useful if vascular pathology is known or suspected.	O
CTA head with IV contrast	2		☢☢☢
X-ray tomography head	1		☢
X-ray sella	1		☢
Arteriography cerebral	1		☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 5: **Hyperprolactinemia.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with IV contrast	8	Multiplanar thin sellar imaging.	O
MRI head without IV contrast	7	Multiplanar thin sellar imaging.	O
CT head with IV contrast	5		☢☢☢
CT head without and with IV contrast	4	Indicated if MRI is not available or contraindicated.	☢☢☢
CT head without IV contrast	4	Indicated if MRI is not available or contraindicated.	☢☢☢
MRA head without IV contrast	3	May be useful if vascular pathology is known or suspected.	O
MRA head without and with IV contrast	3	May be useful if vascular pathology is known or suspected.	O
CTA head with IV contrast	2	For surgical planning or vascular detail if MRI and MRA are contraindicated.	☢☢☢
X-ray tomography head	1		☢
X-ray sella	1		☢
Arteriography cerebral	1		☢☢☢
Venous sampling petrosal sinus	1	Indicated in unusual cases in which lateralization is indeterminate.	Varies
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Neuroendocrine Imaging**

Variant 6: **Acromegaly/gigantism.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with IV contrast	8	Multiplanar thin sellar imaging.	O
MRI head without IV contrast	7	Multiplanar thin sellar imaging.	O
CT head with IV contrast	5	Indicated if MRI is not available or contraindicated.	☢☢☢
CT head without and with IV contrast	4	Indicated if MRI is not available or contraindicated.	☢☢☢
CT head without IV contrast	4	Indicated if MRI is not available or contraindicated.	☢☢☢
Venous sampling petrosal sinus	3	Indicated in unusual cases in which lateralization is indeterminate.	Varies
MRA head without IV contrast	3	May be useful if vascular pathology is known or suspected.	O
MRA head without and with IV contrast	3	May be useful if vascular pathology is known or suspected.	O
CTA head with IV contrast	2	For surgical planning or vascular detail if MRI and MRA are contraindicated.	☢☢☢
X-ray tomography head	1		☢
X-ray sella	1		☢
Arteriography cerebral	1		☢☢☢
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Variant 7: **Growth hormone deficiency, growth deceleration, panhypopituitarism.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without IV contrast	7	Multiplanar thin sellar imaging.	O
MRI head without and with IV contrast	5	Multiplanar thin sellar imaging.	O
CT head with IV contrast	5	Indicated if MRI is not available or contraindicated.	☢☢☢
CT head without IV contrast	4	Indicated if MRI is not available or contraindicated.	☢☢☢
CT head without and with IV contrast	4	Indicated if MRI is not available or contraindicated.	☢☢☢
MRA head without IV contrast	3	May be useful if vascular pathology is known or suspected.	O
MRA head without and with IV contrast	3	May be useful if vascular pathology is known or suspected.	O
CTA head with IV contrast	2	For surgical planning or vascular detail if MRI and MRA are contraindicated.	☢☢☢
X-ray tomography head	1		☢
X-ray sella	1		☢
Arteriography cerebral	1		☢☢☢
Venous sampling petrosal sinus	1		Varies
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			*Relative Radiation Level

Clinical Condition: **Neuroendocrine Imaging**

Variant 8: **Diabetes insipidus.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without IV contrast	7	Multiplanar thin sellar imaging.	O
MRI head without and with IV contrast	6	Multiplanar thin sellar imaging.	O
CT head with IV contrast	5	Indicated if MRI is not available or contraindicated.	☢ ☢ ☢
CT head without IV contrast	4	Indicated if MRI is not available or contraindicated.	☢ ☢ ☢
CT head without and with IV contrast	4	Indicated if MRI is not available or contraindicated.	☢ ☢ ☢
MRA head without IV contrast	3	May be useful if vascular pathology is known or suspected.	O
MRA head without and with IV contrast	3	May be useful if vascular pathology is known or suspected.	O
CTA head with IV contrast	2	For surgical planning or vascular detail if MRI and MRA are contraindicated.	☢ ☢ ☢
X-ray tomography head	1		☢
X-ray sella	1		☢
Arteriography cerebral	1		☢ ☢ ☢
Venous sampling petrosal sinus	1		Varies
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Variant 9: **Pituitary apoplexy.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with IV contrast	8	Multiplanar thin sellar imaging.	O
MRI head without IV contrast	7	Multiplanar thin sellar imaging.	O
CT head without IV contrast	6	Indicated if MRI is not available or contraindicated.	☢ ☢ ☢
CT head with IV contrast	5	Indicated if MRI is not available or contraindicated.	☢ ☢ ☢
CT head without and with IV contrast	4	Indicated if MRI is not available or contraindicated.	☢ ☢ ☢
CTA head with IV contrast	4		☢ ☢ ☢
MRA head without IV contrast	3	May be useful if vascular pathology is known or suspected.	O
MRA head without and with IV contrast	3	May be useful if vascular pathology is known or suspected.	O
X-ray tomography head	1		☢
X-ray sella	1		☢
Arteriography cerebral	1		☢ ☢ ☢
Venous sampling petrosal sinus	1		Varies
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Clinical Condition: **Neuroendocrine Imaging**

Variant 10: **Postoperative sella.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with IV contrast	8	Multiplanar thin sellar imaging.	O
MRI head without IV contrast	7	Multiplanar thin sellar imaging.	O
CT head with IV contrast	5	CT may be indicated to assess bony anatomy and if MRI is not available or contraindicated.	☢ ☢ ☢
CT head without and with IV contrast	4	CT may be indicated to assess bony anatomy and if MRI is not available or contraindicated.	☢ ☢ ☢
CT head without IV contrast	4	CT may be indicated to assess bony anatomy and if MRI is not available or contraindicated.	☢ ☢ ☢
CTA head with IV contrast	4		☢ ☢ ☢
MRA head without IV contrast	3	May be useful if vascular pathology is known or suspected.	O
MRA head without and with IV contrast	3	May be useful if vascular pathology is known or suspected.	O
X-ray tomography head	1		☢
X-ray sella	1		☢
Arteriography cerebral	1		☢ ☢ ☢
Venous sampling petrosal sinus	1		Varies
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

Variant 11: **Precocious puberty.**

Radiologic Procedure	Rating	Comments	RRL*
MRI head without and with IV contrast	8	Multiplanar thin sellar imaging.	O
MRI head without IV contrast	7	Multiplanar thin sellar imaging.	O
MRA head without IV contrast	3	May be useful if vascular pathology is known or suspected.	O
MRA head without and with IV contrast	3	May be useful if vascular pathology is known or suspected.	O
CT head without IV contrast	2		☢ ☢ ☢
CT head with IV contrast	2		☢ ☢ ☢
CT head without and with IV contrast	2		☢ ☢ ☢
CTA head with IV contrast	2		☢ ☢ ☢
X-ray tomography head	1		☢
X-ray sella	1		☢
Arteriography cerebral	1		☢ ☢ ☢
Venous sampling petrosal sinus	1		Varies
Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			***Relative Radiation Level**

NEUROENDOCRINE IMAGING

Expert Panel on Neurologic Imaging: David J. Seidenwurm, MD[1]; Franz J. Wippold II, MD[2]; Rebecca S. Cornelius, MD[3]; Kevin L. Berger, MD[4]; Daniel F. Broderick, MD[5]; Patricia C. Davis, MD[6]; Annette C. Douglas, MD[7]; Kirk A. Frey, MD, PhD[8]; Isabelle M. Germano, MD[9]; Laszlo L. Mechtler, MD[10]; James G. Smirniotopoulos, MD[11]; Michael Vogelbaum, MD, PhD.[12]

Summary of Literature Review

Introduction/Background

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 an 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 [1].

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). PRL 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 [2]. 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 PRL, TSH, GH, ACTH, or gonadotropins. Prolactinomas are the most common and are generally present as microadenomas in premenopausal females with amenorrhea and galactorrhea. PRL 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 optic chiasm, or they may result in hypogonadotropic hypogonadism with loss of libido and impotence [3]. 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 [4]. Nonfunctioning tumors are common, presenting as incidental findings or, if large enough, as compressive lesions.

[1]Radiological Associates of Sacramento, Sacramento, California. [2]Panel Chair, Mallinckrodt Institute of Radiology, Saint Louis, Missouri. [3]Panel Vice-chair, University of Cincinnati, Cincinnati, Ohio. [4]Michigan State University, East Lansing, Michigan. [5]Mayo Clinic Jacksonville, Jacksonville, Florida. [6]Northwest Radiology Consultants, Atlanta, Georgia. [7]Indiana University Hospital, Indianapolis, Indiana. [8]University of Michigan Medical Center, Ann Arbor, Michigan, Society of Nuclear Medicine. [9]Mount Sinai School of Medicine, New York, New York, American Association of Neurological Surgeons/Congress of Neurological Surgeons. [10]Dent Neurologic Institute, Amherst, New York, American Academy of Neurology. [11]Uniformed Services University, Bethesda, Maryland. [12]Cleveland Clinic Main Campus, Cleveland, Ohio, American Association of Neurological Surgeons/Congress of Neurological Surgeons.

Reprint requests to: publications@acr.org

Precocious puberty and other neurological symptoms can be produced by hypothalamic lesions such as hamartomas. MRI is generally indicated in all patients with endocrinologically confirmed precocious puberty, especially when rapid progression of development and neurological symptoms are present [5-10].

Posterior pituitary dysfunction with loss of ADH 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 or of trauma, or can be congenital. Rarely, the hormone is absent 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 the syndrome of inappropriate antidiuretic hormone hypersecretion (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 [11]. In the postpartum period, pituitary infarcts may occur, and hypophysitis is an uncommon disorder resulting in endocrine disturbance and other symptoms [12].

Overview of Imaging Modalities

Classically, radiography and pluridirectional x-ray tomography were the mainstays 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 [13-22]. MRI for sellar pathology includes thin-section multiplanar imaging with slice thickness of 3 mm or less, often before and after contrast administration. Other techniques that are used for evaluating this anatomical region are computed tomography angiography (CTA), magnetic resonance angiography (MRA), direct catheter angiography, and petrosal sinus sampling.

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, used productively in the evaluation of endocrine disease [23].

Computed Tomography

CT detects pituitary microadenomas and macroadenomas [15,24-27]. It is, however, difficult to distinguish tumor from the optic chiasm and to diagnose cavernous invasion. Also, 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 acceptable diagnostic accuracy, though the examinations are sometimes hard to interpret despite excellent technique [28].

Magnetic Resonance Imaging

MRI provides excellent noninvasive evaluation of the hypothalamus and pituitary gland [29-54]. 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 [55-67]. It is technically reproducible and is considered the study of choice for virtually all patients with suspected neuroendocrine pathology.

The addition of gadolinium contrast facilitates diagnosis of microadenoma and increases the confidence with which cavernous sinus invasion can be diagnosed or excluded [68,69]. The specific bony landmarks may be difficult to demonstrate, but the signal pattern of sphenoid sinus mucosa permits assessment of septa for operative planning [70,71]. Visualization of vascular structures in the parasellar region or even intrasellar carotid artery loop or aneurysm is crucial in some cases. Dynamic contrast-enhanced imaging of the pituitary is advocated by some authors, but its value is not confirmed by systematically collected data.

Angiography

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 [72]. Vascular lesions are depicted reliably by MRA.

Petrosal Sinus Venous Sampling

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 [73]. When a significant discrepancy in hormone level, usually ACTH, exists between the vessels studied, tumor localization is very accurate. Complications are rare in experienced hands [74,75].

Problems Imaging the Pituitary

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 optic 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, pregnancy, and menopause. Pituitary hyperplasia in hypothyroidism may simulate a pituitary adenoma in some patients. Also, in patients with intracranial hypotension the gland may appear more prominent than normal [76]. Similar problems arise in imaging the posterior pituitary, since up to 29% of normal subjects do not demonstrate a bright posterior pituitary [77,78].

Summary

- MRI dedicated to the sella is the investigation of choice for disorders of the hypothalamic pituitary axis.
- Neuroradiological evaluation is usually not indicated in the evaluation of obesity.
- Pituitary apoplexy is an acute event in which urgent imaging in indicated.
- Rigorous correlation with endocrine findings is required, since normal subjects often exhibit imaging abnormalities of the pituitary gland.

Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® Radiation Dose Assessment Introduction document.

Relative Radiation Level Designations		
Relative Radiation Level*	**Adult Effective Dose Estimate Range**	**Pediatric Effective Dose Estimate Range**
O	0 mSv	0 mSv
☢	<0.1 mSv	<0.03 mSv
☢ ☢	0.1-1 mSv	0.03-0.3 mSv
☢ ☢ ☢	1-10 mSv	0.3-3 mSv
☢ ☢ ☢ ☢	10-30 mSv	3-10 mSv
☢ ☢ ☢ ☢ ☢	30-100 mSv	10-30 mSv
*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as "Varies".		

Supporting Documents

For additional information on the Appropriateness Criteria methodology and other supporting documents go to www.acr.org/ac.

References

1. Shah S, Waldman AD, Mehta A. Advances in pituitary imaging technology and future prospects. *Best Pract Res Clin Endocrinol Metab.* 2012;26(1):35-46.
2. 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.
3. Isik S, Berker D, Tutuncu YA, et al. Clinical and radiological findings in macroprolactinemia. *Endocrine.* 2012;41(2):327-333.
4. Lieberman S. Diseases of the pituitary. In: Fishman MC, et al, ed. *Medicine*. Philadelphia, Pa.: Lippincott-Raven Publishers; 1996:165.
5. 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.
6. Freeman JL, Coleman LT, Wellard RM, et al. MR imaging and spectroscopic study of epileptogenic hypothalamic hamartomas: analysis of 72 cases. *AJNR Am J Neuroradiol.* 2004;25(3):450-462.
7. 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.
8. 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; discussion 414-418.
9. 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 Suppl 3:8-14.
10. Iorgi ND, Allegri AE, Napoli F, et al. The use of neuroimaging for assessing disorders of pituitary development. *Clin Endocrinol (Oxf).* 2012;76(2):161-176.
11. Flanagan EP, Hunderfund AL, Giannini C, Meissner I. Addition of magnetic resonance imaging to computed tomography and sensitivity to blood in pituitary apoplexy. *Arch Neurol.* 2011;68(10):1336-1337.
12. Pisaneschi M, Kapoor G. Imaging the sella and parasellar region. *Neuroimaging Clin N Am.* 2005;15(1):203-219.
13. Chakeres DW, Curtin A, Ford G. Magnetic resonance imaging of pituitary and parasellar abnormalities. *Radiol Clin North Am.* 1989;27(2):265-281.
14. De Herder WW, Lamberts SW. Imaging of pituitary tumours. *Baillieres Clin Endocrinol Metab.* 1995;9(2):367-389.
15. Dietemann JL, Cromero C, Tajahmady T, et al. CT and MRI of suprasellar lesions. *J Neuroradiol.* 1992;19(1):1-22.
16. Donovan JL, Nesbit GM. Distinction of masses involving the sella and suprasellar space: specificity of imaging features. *AJR Am J Roentgenol.* 1996;167(3):597-603.
17. Elster AD. Imaging of the sella: anatomy and pathology. *Semin Ultrasound CT MR.* 1993;14(3):182-194.

18. Glick RP, Tiesi JA. Subacute pituitary apoplexy: clinical and magnetic resonance imaging characteristics. *Neurosurgery.* 1990;27(2):214-218; discussion 218-219.
19. 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.
20. 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.
21. 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.
22. 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.
23. Isaacs RS, Donald PJ. Sphenoid and sellar tumors. *Otolaryngol Clin North Am.* 1995;28(6):1191-1229.
24. Bonneville JF, Cattin F, Dietemann JL. Hypothalamic-pituitary region: computed tomography imaging. *Baillieres Clin Endocrinol Metab.* 1989;3(1):35-71.
25. Carr DH, Sandler LM, Joplin GF. Computed tomography of sellar and parasellar lesions. *Clin Radiol.* 1984;35(4):281-286.
26. 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.
27. Hershey BL. Suprasellar masses: diagnosis and differential diagnosis. *Semin Ultrasound CT MR.* 1993;14(3):215-231.
28. Glastonbury CM, Osborn AG, Salzman KL. Masses and malformations of the third ventricle: normal anatomic relationships and differential diagnoses. *Radiographics.* 2011;31(7):1889-1905.
29. Aleksandrov N, Audibert F, Bedard MJ, Mahone M, Goffinet F, Kadoch IJ. Gestational diabetes insipidus: a review of an underdiagnosed condition. *J Obstet Gynaecol Can.* 2010;32(3):225-231.
30. Batista DL, Riar J, Keil M, Stratakis CA. Diagnostic tests for children who are referred for the investigation of Cushing syndrome. *Pediatrics.* 2007;120(3):e575-586.
31. Bihan H, Christozova V, Dumas JL, et al. Sarcoidosis: clinical, hormonal, and magnetic resonance imaging (MRI) manifestations of hypothalamic-pituitary disease in 9 patients and review of the literature. *Medicine (Baltimore).* 2007;86(5):259-268.
32. Castro LH, Ferreira LK, Teles LR, et al. Epilepsy syndromes associated with hypothalamic hamartomas. *Seizure.* 2007;16(1):50-58.
33. Cortet-Rudelli C, Sapin R, Bonneville JF, Brue T. Etiological diagnosis of hyperprolactinemia. *Ann Endocrinol (Paris).* 2007;68(2-3):98-105.
34. Delman BN, Fatterpekar GM, Law M, Naidich TP. Neuroimaging for the pediatric endocrinologist. *Pediatr Endocrinol Rev.* 2008;5 Suppl 2:708-719.
35. Donadio F, Barbieri A, Angioni R, et al. Patients with macroprolactinaemia: clinical and radiological features. *Eur J Clin Invest.* 2007;37(7):552-557.
36. Dutta P, Bhansali A, Singh P, Rajput R, Khandelwal N, Bhadada S. Congenital hypopituitarism: clinico-radiological correlation. *J Pediatr Endocrinol Metab.* 2009;22(10):921-928.
37. Ebner FH, Kuerschner V, Dietz K, Bueltmann E, Naegele T, Honegger J. Reduced intercarotid artery distance in acromegaly: pathophysiologic considerations and implications for transsphenoidal surgery. *Surg Neurol.* 2009;72(5):456-460; discussion 460.
38. Friedman TC, Zuckerbraun E, Lee ML, Kabil MS, Shahinian H. Dynamic pituitary MRI has high sensitivity and specificity for the diagnosis of mild Cushing's syndrome and should be part of the initial workup. *Horm Metab Res.* 2007;39(6):451-456.
39. Garel C, Leger J. Contribution of magnetic resonance imaging in non-tumoral hypopituitarism in children. *Horm Res.* 2007;67(4):194-202.
40. Glezer A, Paraiba DB, Bronstein MD. Rare sellar lesions. *Endocrinol Metab Clin North Am.* 2008;37(1):195-211, x.
41. Jagannathan J, Kanter AS, Sheehan JP, Jane JA, Jr., Laws ER, Jr. Benign brain tumors: sellar/parasellar tumors. *Neurol Clin.* 2007;25(4):1231-1249, xi.
42. Kumar J, Kumar A, Sharma R, Vashisht S. Magnetic resonance imaging of sellar and suprasellar pathology: a pictorial review. *Curr Probl Diagn Radiol.* 2007;36(6):227-236.
43. Kunii N, Abe T, Kawamo M, Tanioka D, Izumiyama H, Moritani T. Rathke's cleft cysts: differentiation from other cystic lesions in the pituitary fossa by use of single-shot fast spin-echo diffusion-weighted MR imaging. *Acta Neurochir (Wien).* 2007;149(8):759-769; discussion 769.

44. Lee CT, Tung YC, Tsai WY. Etiology and clinical features of isosexual precocious puberty in Taiwanese girls: twenty-three years' experience in National Taiwan University Hospital. *J Pediatr Endocrinol Metab.* 2009;22(10):947-953.
45. Li G, Shao P, Sun X, Wang Q, Zhang L. Magnetic resonance imaging and pituitary function in children with panhypopituitarism. *Horm Res Paediatr.* 2010;73(3):205-209.
46. Maiya B, Newcombe V, Nortje J, et al. Magnetic resonance imaging changes in the pituitary gland following acute traumatic brain injury. *Intensive Care Med.* 2008;34(3):468-475.
47. Mehta A, Hindmarsh PC, Mehta H, et al. Congenital hypopituitarism: clinical, molecular and neuroradiological correlates. *Clin Endocrinol (Oxf).* 2009;71(3):376-382.
48. Molitch ME, Gillam MP. Lymphocytic hypophysitis. *Horm Res.* 2007;68 Suppl 5:145-150.
49. Murad-Kejbou S, Eggenberger E. Pituitary apoplexy: evaluation, management, and prognosis. *Curr Opin Ophthalmol.* 2009;20(6):456-461.
50. Rambaldini GM, Butalia S, Ezzat S, Kucharczyk W, Sawka AM. Clinical predictors of advanced sellar masses. *Endocr Pract.* 2007;13(6):609-614.
51. Rao VJ, James RA, Mitra D. Imaging characteristics of common suprasellar lesions with emphasis on MRI findings. *Clin Radiol.* 2008;63(8):939-947.
52. Rennert J, Doerfler A. Imaging of sellar and parasellar lesions. *Clin Neurol Neurosurg.* 2007;109(2):111-124.
53. Sahdev A, Reznek RH, Evanson J, Grossman AB. Imaging in Cushing's syndrome. *Arq Bras Endocrinol Metabol.* 2007;51(8):1319-1328.
54. Schneider HJ, Aimaretti G, Kreitschmann-Andermahr I, Stalla GK, Ghigo E. Hypopituitarism. *Lancet.* 2007;369(9571):1461-1470.
55. 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.
56. 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.
57. 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 (Oxf).* 1993;39(3):307-313.
58. 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 Am J Roentgenol.* 1988;151(5):1015-1023.
59. Jafar JJ, Crowell RM. Parasellar and optic nerve lesions: the neurosurgeon's perspective. *Radiol Clin North Am.* 1987;25(4):877-892.
60. 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 (Oxf).* 1992;36(4):335-338.
61. 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.
62. 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.
63. 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.
64. 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.
65. 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.
66. 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.
67. 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.
68. Macpherson P, Hadley DM, Teasdale E, Teasdale G. Pituitary microadenomas. Does Gadolinium enhance their demonstration? *Neuroradiology.* 1989;31(4):293-298.
69. Tripathi S, Ammini AC, Bhatia R, et al. Cushing's disease: pituitary imaging. *Australas Radiol.* 1994;38(3):183-186.
70. 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.

71. 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.
72. 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.
73. 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.
74. Shi X, Sun Q, Bian L, et al. Assessment of Bilateral Inferior Petrosal Sinus Sampling in the diagnosis and surgical treatment of the ACTH-dependent Cushing's syndrome: A comparison with other tests. *Neuro Endocrinol Lett.* 2011;32(6):865-873.
75. Deipolyi AR, Hirsch JA, Oklu R. Bilateral inferior petrosal sinus sampling. *J Neurointerv Surg.* 2012;4(3):215-218.
76. Schievink WI. Spontaneous spinal cerebrospinal fluid leaks and intracranial hypotension. *JAMA.* 2006;295(19):2286-2296.
77. 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.
78. 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.