American College of Radiology
ACR Appropriateness Criteria®
Neuroendocrine Imaging

Variant 1:   **Adult. Suspected or known hypofunctioning pituitary gland (hypopituitarism, growth hormone deficiency, growth deceleration, panhypopituitarism, hypogonadotropic hypogonadism). Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI sella without and with IV contrast	Usually Appropriate	O
MRI sella without IV contrast	Usually Appropriate	O
CT sella with IV contrast	May Be Appropriate	☢☢☢
MRI sella with IV contrast	May Be Appropriate	O
CT sella without IV contrast	Usually Not Appropriate	☢☢☢
CTA head with IV contrast	Usually Not Appropriate	☢☢☢
MRA head without IV contrast	Usually Not Appropriate	O
MRA head with IV contrast	Usually Not Appropriate	O
MRA head without and with IV contrast	Usually Not Appropriate	O
CT sella without and with IV contrast	Usually Not Appropriate	☢☢☢
Radiography sella	Usually Not Appropriate	☢
Venous sampling petrosal sinus	Usually Not Appropriate	Varies

Variant 2:   **Adult. Suspected or known hyperfunctioning pituitary adenoma (hyperthyroidism [high thyroid-stimulating hormone], Cushing syndrome [high adrenal corticotrophic hormone], hyperprolactinemia, acromegaly, or gigantism). Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI sella without and with IV contrast	Usually Appropriate	O
MRI sella without IV contrast	Usually Appropriate	O
CT sella with IV contrast	May Be Appropriate	☢☢☢
CT sella without IV contrast	May Be Appropriate	☢☢☢
MRI sella with IV contrast	May Be Appropriate	O
CTA head with IV contrast	Usually Not Appropriate	☢☢☢
MRA head with IV contrast	Usually Not Appropriate	O
MRA head without IV contrast	Usually Not Appropriate	O
Venous sampling petrosal sinus	Usually Not Appropriate	Varies
CT sella without and with contrast	Usually Not Appropriate	☢☢☢
MRA head without and with IV contrast	Usually Not Appropriate	O
Radiography sella	Usually Not Appropriate	☢

Variant 3:   Adult. Diabetes insipidus. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
MRI sella without and with IV contrast	Usually Appropriate	O
MRI sella without IV contrast	Usually Appropriate	O
CT sella with IV contrast	May Be Appropriate	☢☢☢
CT sella without IV contrast	May Be Appropriate	☢☢☢
MRI sella with IV contrast	May Be Appropriate	O
CTA head with IV contrast	Usually Not Appropriate	☢☢☢
CT sella without and with IV contrast	Usually Not Appropriate	☢☢☢
MRA head with IV contrast	Usually Not Appropriate	O
MRA head without and with IV contrast	Usually Not Appropriate	O
MRA head without IV contrast	Usually Not Appropriate	O
Radiography sella	Usually Not Appropriate	☢
Venous sampling petrosal sinus	Usually Not Appropriate	Varies

Variant 4:   Adult. Pituitary apoplexy. Initial imaging.

Procedure	Appropriateness Category	Relative Radiation Level
MRI sella without and with IV contrast	Usually Appropriate	O
MRI sella without IV contrast	Usually Appropriate	O
CT sella without IV contrast	May Be Appropriate (Disagreement)	☢☢☢
CT sella with IV contrast	May Be Appropriate	☢☢☢
MRI sella with IV contrast	May Be Appropriate	O
CTA head with IV contrast	Usually Not Appropriate	☢☢☢
CT sella without and with IV contrast	Usually Not Appropriate	☢☢☢
MRA head with IV contrast	Usually Not Appropriate	O
MRA head without and with IV contrast	Usually Not Appropriate	O
MRA head without IV contrast	Usually Not Appropriate	O
Radiography sella	Usually Not Appropriate	☢
Venous sampling petrosal sinus	Usually Not Appropriate	Varies

Variant 5:   **Adult. Surveillance postpituitary or sellar mass resection.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI sella without and with IV contrast	Usually Appropriate	O
MRI sella without IV contrast	Usually Appropriate	O
CT sella with IV contrast	May Be Appropriate	☢☢☢
CT sella without IV contrast	May Be Appropriate	☢☢☢
MRI sella with IV contrast	May Be Appropriate	O
CTA head with IV contrast	Usually Not Appropriate	☢☢☢
CT sella without and with IV contrast	Usually Not Appropriate	☢☢☢
MRA head with IV contrast	Usually Not Appropriate	O
MRA head without IV contrast	Usually Not Appropriate	O
MRA head without and with IV contrast	Usually Not Appropriate	O
Radiography sella	Usually Not Appropriate	☢
Venous sampling petrosal sinus	Usually Not Appropriate	Varies

Variant 6:   **Child, males younger than 9 years of age; females younger than 8 years of age. Precocious puberty. Initial imaging.**

Procedure	Appropriateness Category	Relative Radiation Level
MRI sella without and with IV contrast	Usually Appropriate	O
MRI sella without IV contrast	Usually Appropriate	O
MRI sella with IV contrast	May Be Appropriate	O
CT sella with IV contrast	Usually Not Appropriate	☢☢☢
CT sella without IV contrast	Usually Not Appropriate	☢☢☢
CTA head with IV contrast	Usually Not Appropriate	☢☢☢☢
CT sella without and with IV contrast	Usually Not Appropriate	☢☢☢
MRA head with IV contrast	Usually Not Appropriate	O
MRA head without and with IV contrast	Usually Not Appropriate	O
MRA head without IV contrast	Usually Not Appropriate	O
Radiography sella	Usually Not Appropriate	☢
Venous sampling petrosal sinus	Usually Not Appropriate	Varies

NEUROENDOCRINE IMAGING

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Summary of Literature Review

Introduction/Background

Neuroendocrine abnormalities encompass a range of centrally mediated hormonal imbalances and organ-specific pituitary abnormalities. Imaging is generally focused on the pituitary gland and parasellar region and typically follows endocrine evaluation [1-3]. Abnormalities of the pituitary are often an incidental finding on imaging performed for other indications, though these may be associated with occult endocrine dysfunction [4], and focused imaging is commonly requested in follow-up of these lesions. Extrinsic mass effect can result in dysregulation of pituitary hormone release as well as extra-pituitary dysfunction.

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, adrenal corticotrophic hormone, prolactin, growth hormone, and the gonadotropins. These are secreted under the influence of hypothalamic trophic factors. 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. The hypothalamus also participates in complex mediation of food intake, temperature regulation, sleep and arousal, memory, thirst, and other autonomic functions.

This document encompasses the most common hypothalamic pituitary axis neuroendocrine abnormalities in adults. Thyroid and thyroid-releasing hormone-induced abnormalities are covered in the ACR Appropriateness Criteria® topic on "Thyroid Disease" [5]. This document is not intended to guide the evaluation of neuroendocrine abnormalities in childhood, with the exception of Variant 6: Precocious puberty. The follow-up of incidentally detected pituitary lesions on MRI should be guided by the "Management of Incidental Pituitary Findings on CT, MRI, and (18)F-Fluorodeoxyglucose PET: A White Paper of the ACR Incidental Findings Committee" [6].

Special Imaging Considerations

This guideline emphasizes the initial imaging for diagnosis. Additional studies may be ordered specifically for image-guided surgical navigation systems or intraoperative imaging platforms. It is recommended that ordering physicians consult with their radiologists as to protocols that can accomplish surgical guidance needs, to minimize patient recall or reimaging [7-10]. Endoscopic surgical landmarks requiring presurgical assessment include evaluation for presence of sinus inflammatory disease, sphenoid sinus pneumatization, bony spurs, variant anatomy, and bony dehiscence overlying the internal carotid arteries within the sphenoid sinuses [11-13].

Discussion of Procedures by Variant

Variant 1: Adult. Suspected or known hypofunctioning pituitary gland (hypopituitarism, growth hormone deficiency, growth deceleration, panhypopituitarism, hypogonadotropic hypogonadism). Initial imaging.

Pituitary hypofunction can be caused by mass effect from extrinsic solid or cystic lesions, or from intrinsic pituitary abnormalities. Small prolactin-secreting adenomas in males may result in hypogonadotropic

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hypogonadism, with loss of libido and impotence [14]. Other common mass lesions that may affect the neuroendocrine system are germ-line tumors, meningioma, craniopharyngioma, and Rathke cleft cyst, among others [2,15-18]. Metastatic lesions, sarcoid, and other inflammatory processes may involve the sella and parasellar regions as well. Additionally, an empty sella may be seen with herniation of the subarachnoid space into the sella turcica; while this is usually an incidental finding, close to 30% of patients may demonstrate some hypopituitarism upon testing [19].

CT Sella
CT can be used to detect bone-destructive lesions of the skull base, which may affect the sella turcica and can also detect larger macroadenomas. Even with an optimized technique, CT for pituitary pathology is insensitive when compared to MRI [12]. Intravenous (IV) contrast may be useful to characterize lesions or assess for soft-tissue invasion, but it should not be considered a first-line imaging test. CT using dual-energy techniques may discriminate larger pituitary masses from other lesions, such as meningioma [18]. Solid masses are more easily defined compared to cystic lesions, which may be confused with cerebral spinal fluid in the suprasellar cistern. CT features of selected suprasellar masses may aid in their characterization. Tumor invasion of the cavernous sinuses can be difficult to detect and may be aided by IV contrast as an adjunctive test. Dual-phase imaging with and without IV contrast is not indicated as an initial imaging study. Thin-section acquisition with multiplanar reformatting is essential and vastly improved over direct coronal imaging. This can also aid intraoperative navigation and provide greater osseous detail for anatomy in the sphenoid sinus prior to trans-sphenoidal surgery.

CTA Head
CT angiography (CTA) is indicated when vascular lesions, such as aneurysm, are suspected, though these rarely cause clinical symptoms referable to the hypothalamic pituitary axis. Cavernous sinus invasion by pituitary masses can be better detected with CTA compared with noncontrast CT. CTA may be part of operative planning or image guidance; however, CTA is not routinely used for initial evaluation [20].

MRA Head
MR angiography (MRA) can be a useful adjunct to pituitary MRI and can reliably depict vascular lesions, such as aneurysms [21,22], though these rarely cause clinical symptoms referable to the hypothalamic pituitary axis. Displacement or encasement of vessels in the suprasellar region can be better defined with MRA for surgical planning; however, MRA is not routinely used for initial evaluation.

MRI Sella
MRI using high-resolution pituitary protocols is the preferred diagnostic imaging modality for evaluation of the pituitary and sellar regions [1,2,23-28]. Anatomy and pathologies involving the pituitary gland, infundibulum, optic chiasm, and vascular structures are reliably depicted and can be characterized on both precontrast and postcontrast imaging, particularly with the aid of high-resolution, focused field-of-view sequences targeted for sellar and parasellar assessment [29-63]. MRI with and without IV contrast plays an important role in characterizing lesions of the sella, suprasellar cistern, and any cavernous sinus invasion [64,65]. MRI with IV contrast may only be performed for use in operative guidance, and should not be considered a first-line imaging test. MRI can confirm absence or ectopia of the posterior pituitary gland. Pituitary underdevelopment may be suggested on the basis of imaging; however, objective criteria for pituitary hypoplasia do not exist [40,42,48]. An empty sella is well characterized on MRI, even without IV contrast [19].

Venous Sampling Petrosal Sinus
Venous sampling of the cavernous sinuses is not useful in the setting of pituitary hypofunction. Venous sampling is reserved for cases in which a definite excess of pituitary hormone is present, medical management has failed, cross-sectional imaging is negative or equivocal, and surgery is planned [66-68].

Radiography Sella
Radiography is insensitive and nonspecific for evaluating sellar pathology. Pituitary adenomas are frequently associated with a normal sella size. The sella turcica can be enlarged by the presence of a pituitary adenoma or other pathophysiological conditions such as pulsation of cerebral spinal fluid through a developmental or acquired dehiscence of the diaphragm sella in the empty sella syndrome [69].

Variant 2: Adult. Suspected or known hyperfunctioning pituitary adenoma (hyperthyroidism [high thyroid-stimulating hormone], Cushing syndrome [high adrenal corticotrophic hormone], hyperprolactinemia, acromegaly, or gigantism). Initial imaging.

Pituitary adenomas are the most common lesions of the pituitary gland in an adult. In cases of suspected endocrine hyperfunction, imaging is indicated to identify, characterize, monitor, and plan for the surgical treatment of tumors [1-3,23-27]. Tumors may respond to medical treatment with dopamine analogs or other medications. Pituitary adenomas may grow large but are most commonly hormone-secreting when small (microadenoma <10 mm); in premenopausal females, microadenomas most commonly present with clinical symptoms of amenorrhea and galactorrhea, although these symptoms may also result from a variety of other medical, neurological, or pharmacological causes. In males, prolactinomas may be entirely asymptomatic until visual symptoms occur, which is due to compression of the optic chiasm, or they may result in hypogonadotropic hypogonadism with loss of libido and impotence [14]. Thyroid and thyroid-releasing hormone-induced abnormalities are covered used the ACR Appropriateness Criteria® topic on "Thyroid Disease" [5].

CT Sella

CT has the ability to identify large pituitary tumors, and contrast-enhanced CT may define some microadenomas [28,70-73], although MRI is more sensitive. Dual-phase imaging with and without IV contrast is not indicated as an initial imaging study. Larger tumors may cause sellar remodeling, including sellar enlargement, bony erosion, supra sellar extension, invasion into the clivus, or sphenoid sinus.

CTA Head

CTA may be part of operative planning or image guidance; however, CTA is not routinely used in the initial evaluation of known or suspected hyperfunctioning pituitary adenoma [20].

MRA Head

There is no relevant literature regarding the use of MRA in the initial imaging evaluation of suspected or known hyperfunctioning pituitary adenoma.

MRI Sella

MRI using high-resolution pituitary protocols is generally considered the gold standard for imaging the pituitary gland in cases of suspected hormone-secreting adenoma [15]. MRI can directly visualize the pituitary gland on noncontrast sequences. The addition of IV contrast increases the conspicuity of small adenomas, which are typically seen as hypoenhancing lesions [13,74,75]. MRI with IV contrast may only be performed for use in operative guidance, and should not be considered a first-line imaging test. MRI has been used to characterize tissue consistency [76] and has been used to predict response to therapy in cases of acromegaly [77]. Dynamic contrast-enhanced imaging of the pituitary is advocated by some authors for detection of microadenoma [78-80]. Additionally, recent studies have noted an increased sensitivity for spoiled gradient-echo 3-D T1 sequence in the detection of hormone-secreting adenomas [81]. Hormone-secreting pituitary tumors are more commonly microadenomas (<10 mm), highlighting the need for high-resolution, focused field-of-view, and thin-section imaging. MRI may further characterize hemorrhage within adenomas as areas of decreased signal intensity on T2-weighted images [41,60].

Venous Sampling Petrosal Sinus

Petrosal sinus venous sampling is an invasive study reserved for cases in which a definite excess of pituitary hormone is present, medical management has failed, cross-sectional imaging is negative or equivocal, and surgery is planned [67]. When a significant discrepancy in hormone level, usually adrenal corticotrophic hormone, exists between the petrosal sinus and peripheral blood samples, tumor localization is very accurate [66,68].

Radiography Sella

There is no relevant literature regarding the use of radiography in the initial evaluation of known or suspected hyperfunctioning pituitary adenoma.

Variant 3: Adult. Diabetes insipidus. Initial imaging.

Central causes of diabetes insipidus may be associated with abnormalities affecting the pituitary stalk and the hypothalamic-pituitary axis. Mass effect or neoplastic invasion may be present because of germ-line tumors, lymphoma, leukemia, Langerhans cell histiocytosis, metastasis, craniopharyngioma, meningioma, and Rathke cleft cyst, among others [2,15-17]. Inflammatory processes (ie, sarcoid, lymphocytic hypophysitis, granulomatous infiltration) occur in the sellar and suprasellar regions as well. Additionally, an empty sella may be seen with

herniation of the subarachnoid space into the sella turcica; this is usually an incidental finding, close to 30% of patients may demonstrate some hypopituitarism upon testing [19].

CT Sella

CT can detect solid lesions of the suprasellar cistern and may detect infiltrative lesions of the pituitary stalk but also may miss cystic tumors. Multiplanar reconstructions with thin sections and soft-tissue window settings are crucial to visualize the suprasellar cistern and pituitary stalk. CT with IV contrast helps to visualize the enhancing pituitary stalk and infiltrative lesions of the stalk, though MRI is considered the best first-line study. Dual-phase imaging with and without IV contrast is not indicated as an initial imaging study.

CTA Head

CTA may be part of operative planning or image guidance; however, CTA is not routinely used for initial evaluation of diabetes insipidus [20].

MRA Head

There is no relevant literature regarding the use of MRA in the evaluation of diabetes insipidus.

MRI Sella

MRI with and without IV contrast using high-resolution pituitary or skull base protocols is preferred in the workup of suspected central diabetes insipidus and in the detection of abnormalities of the hypothalamic-neurohypophyseal axis, which may lead to failure of normal antidiuretic hormone release and transport. Thin-section T1-weighted images are used to directly identify typical T1 signal hyperintensity of normal neurosecretory granules; such a signal may be absent from the sella when an ectopic posterior pituitary gland is present or in long-standing diabetes insipidus. Traumatic etiologies, such as stalk transection or postoperative sella, can be characterized using thin-section T2-weighted images. MRI with and without IV contrast is especially useful for the detection and characterization of inflammatory lesions of the stalk and neoplastic invasion [23,82]. MRI with IV contrast may only be performed for use in operative guidance and should not be considered a first-line imaging test.

Venous Sampling Petrosal Sinus

There is no relevant literature regarding the use of venous sampling in the evaluation of diabetes insipidus.

Radiography Sella

There is no relevant literature regarding the use of radiography in the evaluation of diabetes insipidus.

Variant 4: Adult. Pituitary apoplexy. Initial imaging.

Pituitary apoplexy refers to sudden onset of neurological symptoms and hormonal dysfunction related to either hemorrhagic or vascular impairment of the pituitary gland [3,83]. Imaging is often used to detect pituitary hemorrhage, which can occur as the initial manifestation of an adenoma or in the clinical setting of treated adenoma, prior radiation treatment, pregnancy (see the "Safety Considerations in Pregnant Patients" section below), anticoagulation, and trauma.

CT Sella

CT may provide useful information in the clinical setting of sudden onset of pituitary dysfunction by identifying a pituitary or suprasellar mass but is less sensitive than MRI for the detection of acute pituitary hemorrhage [16]. MRI is considered the optimal first-line test. Calcification seen on CT may help to clarify complicated cases of craniopharyngioma, which can occasionally be confused with hemorrhagic pituitary adenoma on MRI. While the use of IV contrast may help distinguish hemorrhage from enhancement, dual-phase imaging with and without IV contrast is not indicated as an initial imaging study. As pituitary apoplexy may clinically present with sudden headache and oculomotor palsies; CT may be considered as part of the initial diagnostic evaluation to exclude intracranial hemorrhage or mass lesion, particularly when rapid diagnosis is needed, such as in an emergency department setting.

CTA Head

CTA may be part of operative planning or image guidance; however, CTA is not routinely used for initial evaluation of pituitary apoplexy [20].

MRA Head

There is no relevant literature regarding the use of MRA in the evaluation of pituitary apoplexy.

MRI Sella

MRI using high-resolution pituitary protocols is the primary modality for the evaluation of suspected pituitary apoplexy [83]. Tumor enlargement, sellar expansion, and intratumoral hemorrhage are well demonstrated on MRI. Noncontrast imaging is sensitive to the detection of hemorrhage and may show T1 signal hyperintensity, low T2 signal, or a hemorrhage fluid level within the pituitary gland [84]. Not all cases of intrapituitary hemorrhage (ie, subacute/necrotic adenoma) are associated with symptomatic pituitary apoplexy; however, caution is needed in interpreting pituitary hemorrhage in the context of clinical symptoms [85]. While pituitary apoplexy is most commonly caused by hemorrhage into an existing pituitary macroadenoma, other soft-tissue masses may have overlapping imaging features. For example, craniopharyngioma or Rathke cleft cysts can have intrinsic T1-signal hyperintensity that is due to proteinaceous content, and a dermoid or teratoma may show high T1 signal because of fat. Inclusion of T1 fat saturation sequences may aid in differentiation of fat from blood products. Ischemic pituitary apoplexy can be detected on contrast-enhanced MRI in the appropriate clinical context by central nonenhancement of the enlarged pituitary, indicating central tumoral necrosis or ischemia. MRI with IV contrast may only be performed for use in operative guidance and should not be considered a first-line imaging test.

Venous Sampling Petrosal Sinus

There is no relevant literature regarding the use of venous sampling in the evaluation of pituitary apoplexy.

Radiography Sella

There is no relevant literature regarding the use of radiography in the evaluation of pituitary apoplexy.

Variant 5: Adult. Surveillance postpituitary or sellar mass resection.

Delayed surveillance is performed in patients with known subtotal pituitary adenoma resection [86], nonfunctioning pituitary adenomas [87], and postresection of sellar/suprasellar nonadenoma masses guided by tumor pathology and patient symptoms. In the immediate postoperative setting, local complications may be difficult to discern from normal postoperative changes [88,89]. There is variable literature regarding the frequency and duration of routine follow-up for nonfunctioning tumors [90,91]; however, postoperative imaging is often performed >3 months following trans-sphenoidal surgery [88].

Imaging of suspected operative complications—such as intracranial hemorrhage, vascular injury, infarct [92], infection [93], or cerebrospinal fluid leak [94]—are beyond the scope of this document.

CT Sella

Assessment for tumor growth or suprasellar extension can be performed using CT, although MRI is generally considered superior. Invasion of the skull base by pituitary tumor is an uncommon but important complication that is best characterized preoperatively with CT [95]. CT with IV contrast is not typically needed in the postoperative setting, unless specifically focused on adjacent structures such as the cavernous sinuses. Dual-phase imaging with and without IV contrast is not indicated as an initial imaging study.

CTA Head

Routine vascular imaging following pituitary surgery is generally not indicated unless there is known or clinical suspicion for a vascular complication.

MRA Head

Routine vascular imaging following pituitary surgery is generally not indicated unless there is known or clinical suspicion for a vascular complication.

MRI Sella

MRI using high-resolution pituitary protocols is the most useful tool for diagnostic assessment following pituitary surgery. MRI with and without IV contrast adds additional information when new tumor is suspected in the setting of gross total tumor resection [86], surveillance of smaller known masses [64], and hormone-secreting microadenomas when there is an unexpected hormonal response to medical therapy. In patients with known tumors and normal hormone levels on dopamine agonist therapy, MRI follow-up may be unnecessary [96]. Inclusion of diffusion-weighted imaging may be considered as a tool to differentiate granulation tissue postoperative from residual or recurrent adenoma [97]. Surveillance after resection of nonadenoma sellar/suprasellar masses should be based on the tumor pathology and patient symptoms, generally requiring MRI without and with IV contrast. High-resolution pituitary protocols generally suffice for the assessment of

cavernous sinus involvement or complication. MRI with IV contrast may only be performed for use in operative guidance and should not be considered for routine surveillance.

Venous Sampling Petrosal Sinus
There is no relevant literature regarding the use of venous sampling in the evaluation of the postoperative sella.

Radiography Sella
There is no relevant literature regarding the use of radiography in the evaluation of the postoperative sella.

Variant 6: Child, males younger than 9 years of age; females younger than 8 years of age. Precocious puberty. Initial imaging.

Central causes of precocious puberty are often idiopathic; however, this may be related to intracranial neoplasms, trauma, infection, hydrocephalus, and some syndromes with premature gonadotropin-releasing hormone production that is due to infiltration or extrinsic mass effect [98-103].

The appropriateness of imaging in the setting of precocious puberty is debated. Imaging should always follow hormonal studies that suggest a central origin of precocious puberty [104,105]. The age of the child at symptom onset is important, where girls <6 and boys younger <9 are most likely to show a central nervous system abnormality and therefore should be screened with MRI [104,106-108]. For girls 6 to 8 years of age, the likelihood of identifying a central nervous system lesion is lower, estimated between 2% to 7%, and neoplastic in 1% [104,109]. The need for routine central nervous system imaging is controversial and requires careful clinical consideration [107,110].

CT Sella
CT provides the ability to evaluate the overall size and structure of the sella turcica but offers little in the way of intrasellar and parasellar soft-tissue detail. Larger lesions in the suprasellar cistern can be identified (ie, germinoma, astrocytoma, arachnoid cyst), as well as gross morphological alterations in the configuration and appearance of the ventricles, such as in the setting of hydrocephalus [111]. CT with IV contrast may highlight a solid mass but is rarely indicated as an initial screening examination.

CTA Head
CTA may be part of operative planning or image guidance; however, CTA is not routinely used for initial evaluation of precocious puberty [20].

MRA Head
There is no relevant literature regarding the use of MRA in the evaluation of precocious puberty.

MRI Sella
MRI is the preferred imaging modality to evaluate the hypothalamic-pituitary axis and parasellar regions with its superior depiction of parenchymal tissue [105,112]. Gadolinium-based contrast adds additional benefit in characterizing lesions. Small pituitary lesions, such as adenomas and Rathke cleft cysts, may be occult without postcontrast sequences. Contrast-enhanced MRI also discriminates between nonenhancing hypothalamic hamartoma and an enhancing astrocytoma. MRI with IV contrast may only be performed for use in operative guidance and should not be considered as a first-line imaging test. MRI is able to detect more subtle mass lesions and directly evaluate pituitary morphology, as well as mass effect, upon the hypothalamus. MRI is appropriate, irrespective of age and gender, in patients with precocious puberty and concurrent central nervous system symptoms, such as severe headaches, visual changes, or seizures [107].

Congenital abnormalities with imaging manifestations, such as septo-optic dysplasia, are better seen on MRI, although [113] these generally manifest symptomatically earlier in childhood and contrast is generally not needed in these circumstances.

Venous Sampling Petrosal Sinus
There is no relevant literature regarding the use of venous sampling in the evaluation of precocious puberty.

Radiography Sella
There is no relevant literature regarding the use of radiography in the evaluation of precocious puberty.

Summary of Recommendations

- **Variant 1:** MRI sella without and with IV contrast or MRI sella without IV contrast is usually appropriate for the initial imaging of adults with suspected or known hypofunctioning pituitary gland (hypopituitarism, growth hormone deficiency, growth deceleration, panhypopituitarism, hypogonadotropic hypogonadism). The addition of IV contrast is preferred for the assessment of pituitary lesions; however, a noncontrast MRI also provides diagnostic detail.

- **Variant 2:** MRI sella without and with IV contrast or MRI sella without IV contrast is usually appropriate for the initial imaging of adults with suspected or known hyperfunctioning pituitary adenoma (hyperthyroidism [high thyroid-stimulating hormone], and Cushing syndrome [high adrenal corticotrophic hormone], hyperprolactinemia, acromegaly, or gigantism). The addition of IV contrast is preferred for the assessment of pituitary lesions; however, a noncontrast MRI also provides diagnostic detail.

- **Variant 3:** MRI sella without and with IV contrast or MRI sella without IV contrast is usually appropriate for the initial imaging of adults with diabetes insipidus. The addition of IV contrast is preferred for the assessment of pituitary lesions; however, a noncontrast MRI also provides diagnostic detail.

- **Variant 4:** MRI sella without and with IV contrast or MRI sella without IV contrast is usually appropriate for the initial imaging of adults with pituitary apoplexy. The addition of IV contrast is preferred for the assessment of pituitary lesions; however, a noncontrast MRI also provides diagnostic detail. The panel did not agree on recommending CT sella without IV contrast for adults in this clinical setting. There is insufficient medical literature to conclude whether or not these patients would benefit from this procedure. The use of CT sella without IV contrast in this patient population is controversial but may be appropriate.

- **Variant 5:** MRI sella without and with IV contrast or MRI sella without IV contrast is usually appropriate in adults when surveillance postpituitary or sellar mass resection is performed. The addition of IV contrast is preferred for the assessment of pituitary lesions; however, a noncontrast MRI also provides diagnostic detail.

- **Variant 6:** MRI sella without and with IV contrast or MRI sella without IV contrast is usually appropriate for the initial imaging of children with precocious puberty, specifically males younger than 9 years of age or females younger than 8 years of age. The addition of IV contrast is preferred for the assessment of pituitary lesions; however, a noncontrast MRI also provides diagnostic detail.

Supporting Documents

The evidence table, literature search, and appendix for this topic are available at https://acsearch.acr.org/list. The appendix includes the strength of evidence assessment and the final rating round tabulations for each recommendation.

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

Safety Considerations in Pregnant Patients

Imaging of the pregnant patient can be challenging, particularly with respect to minimizing radiation exposure and risk. For further information and guidance, see the following ACR documents:

- ACR–SPR Practice Parameter for the Safe and Optimal Performance of Fetal Magnetic Resonance Imaging (MRI) [114]
- ACR-SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation [115]
- ACR-ACOG-AIUM-SRU Practice Parameter for the Performance of Obstetrical Ultrasound [116]
- ACR Manual on Contrast Media [117]
- ACR Guidance Document for MR Safe Practices [118]

Appropriateness Category Names and Definitions

Appropriateness Category Name	Appropriateness Rating	Appropriateness Category Definition
Usually Appropriate	7, 8, or 9	The imaging procedure or treatment is indicated in the specified clinical scenarios at a favorable risk-benefit ratio for patients.
May Be Appropriate	4, 5, or 6	The imaging procedure or treatment may be indicated in the specified clinical scenarios as an alternative to imaging procedures or treatments with a more favorable risk-benefit ratio, or the risk-benefit ratio for patients is equivocal.
May Be Appropriate (Disagreement)	5	The individual ratings are too dispersed from the panel median. The different label provides transparency regarding the panel's recommendation. "May be appropriate" is the rating category and a rating of 5 is assigned.
Usually Not Appropriate	1, 2, or 3	The imaging procedure or treatment is unlikely to be indicated in the specified clinical scenarios, or the risk-benefit ratio for patients is likely to be unfavorable.

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, because of both 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 with 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 [119].

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."		

References

1.   Bonneville JF. Magnetic Resonance Imaging of Pituitary Tumors. Front Horm Res 2016;45:97-120.

2. Go JL, Rajamohan AG. Imaging of the Sella and Parasellar Region. Radiol Clin North Am 2017;55:83-101.

3. Wong A, Eloy JA, Couldwell WT, Liu JK. Update on prolactinomas. Part 1: Clinical manifestations and diagnostic challenges. J Clin Neurosci 2015;22:1562-7.

4. Esteves C, Neves C, Augusto L, et al. Pituitary incidentalomas: analysis of a neuroradiological cohort. Pituitary 2015;18:777-81.

5. American College of Radiology. ACR Appropriateness Criteria®: Thyroid Disease. Available at: https://acsearch.acr.org/docs/3102386/Narrative/. Accessed November 30, 2018.

6. Hoang JK, Hoffman AR, Gonzalez RG, et al. Management of Incidental Pituitary Findings on CT, MRI, and (18)F-Fluorodeoxyglucose PET: A White Paper of the ACR Incidental Findings Committee. J Am Coll Radiol 2018;15:966-72.

7. Eboli P, Shafa B, Mayberg M. Intraoperative computed tomography registration and electromagnetic neuronavigation for transsphenoidal pituitary surgery: accuracy and time effectiveness. J Neurosurg 2011;114:329-35.

8. Locatelli M, Di Cristofori A, Draghi R, et al. Is Complex Sphenoidal Sinus Anatomy a Contraindication to a Transsphenoidal Approach for Resection of Sellar Lesions? Case Series and Review of the Literature. World Neurosurg 2017;100:173-79.

9. Kupferman ME, Hanna E. Robotic surgery of the skull base. Otolaryngol Clin North Am 2014;47:415-23.

10. Garcia-Garrigos E, Arenas-Jimenez JJ, Monjas-Canovas I, et al. Transsphenoidal Approach in Endoscopic Endonasal Surgery for Skull Base Lesions: What Radiologists and Surgeons Need to Know. Radiographics 2015;35:1170-85.

11. Miki Y, Kanagaki M, Takahashi JA, et al. Evaluation of pituitary macroadenomas with multidetector-row CT (MDCT): comparison with MR imaging. Neuroradiology 2007;49:327-33.

12. Glastonbury CM, Osborn AG, Salzman KL. Masses and malformations of the third ventricle: normal anatomic relationships and differential diagnoses. Radiographics 2011;31:1889-905.

13. Patel SN, Youssef AS, Vale FL, Padhya TA. Re-evaluation of the role of image guidance in minimally invasive pituitary surgery: benefits and outcomes. Comput Aided Surg 2011;16:47-53.

14. Isik S, Berker D, Tutuncu YA, et al. Clinical and radiological findings in macroprolactinemia. Endocrine 2012;41:327-33.

15. Chakeres DW, Curtin A, Ford G. Magnetic resonance imaging of pituitary and parasellar abnormalities. Radiol Clin North Am 1989;27:265-81.

16. Pisaneschi M, Kapoor G. Imaging the sella and parasellar region. Neuroimaging Clin N Am 2005;15:203-19.

17. Spampinato MV, Castillo M. Congenital pathology of the pituitary gland and parasellar region. Top Magn Reson Imaging 2005;16:269-76.

18. Wu LM, Li YL, Yin YH, et al. Usefulness of dual-energy computed tomography imaging in the differential diagnosis of sellar meningiomas and pituitary adenomas: preliminary report. PLoS One 2014;9:e90658.

19. Guitelman M, Garcia Basavilbaso N, Vitale M, et al. Primary empty sella (PES): a review of 175 cases. Pituitary 2013;16:270-4.

20. Macpherson P, Teasdale E, Hadley DM, Teasdale G. Invasive v non-invasive assessment of the carotid arteries prior to trans-sphenoidal surgery. Neuroradiology 1987;29:457-61.

21. Heshmati HM, Fatourechi V, Dagam SA, Piepgras DG. Hypopituitarism caused by intrasellar aneurysms. Mayo Clin Proc 2001;76:789-93.

22. Weir B. Pituitary tumors and aneurysms: case report and review of the literature. Neurosurgery 1992;30:585-91.

23. Abele TA, Yetkin ZF, Raisanen JM, Mickey BE, Mendelsohn DB. Non-pituitary origin sellar tumours mimicking pituitary macroadenomas. Clin Radiol 2012;67:821-7.

24. Akhare PJ, Dagab AM, Alle RS, Shenoyd U, Garla V. Comparison of landmark identification and linear and angular measurements in conventional and digital cephalometry. Int J Comput Dent 2013;16:241-54.

25. Bresson D, Herman P, Polivka M, Froelich S. Sellar Lesions/Pathology. Otolaryngol Clin North Am 2016;49:63-93.

26. Famini P, Maya MM, Melmed S. Pituitary magnetic resonance imaging for sellar and parasellar masses: ten-year experience in 2598 patients. J Clin Endocrinol Metab 2011;96:1633-41.

27. Hess CP, Dillon WP. Imaging the pituitary and parasellar region. Neurosurg Clin N Am 2012;23:529-42.

28. Dietemann JL, Cromero C, Tajahmady T, et al. CT and MRI of suprasellar lesions. J Neuroradiol 1992;19:1-22.
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;32:225-31.
30. Argyropoulou M, Perignon F, Brauner R, Brunelle F. Magnetic resonance imaging in the diagnosis of growth hormone deficiency. J Pediatr 1992;120:886-91.
31. Batista DL, Riar J, Keil M, Stratakis CA. Diagnostic tests for children who are referred for the investigation of Cushing syndrome. Pediatrics 2007;120:e575-86.
32. 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;86:259-68.
33. 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;143:493-6.
34. Castro LH, Ferreira LK, Teles LR, et al. Epilepsy syndromes associated with hypothalamic hamartomas. Seizure 2007;16:50-8.
35. Cortet-Rudelli C, Sapin R, Bonneville JF, Brue T. Etiological diagnosis of hyperprolactinemia. Ann Endocrinol (Paris) 2007;68:98-105.
36. Delman BN, Fatterpekar GM, Law M, Naidich TP. Neuroimaging for the pediatric endocrinologist. Pediatr Endocrinol Rev 2008;5 Suppl 2:708-19.
37. Donadio F, Barbieri A, Angioni R, et al. Patients with macroprolactinaemia: clinical and radiological features. Eur J Clin Invest 2007;37:552-7.
38. Dutta P, Bhansali A, Singh P, Rajput R, Khandelwal N, Bhadada S. Congenital hypopituitarism: clinico-radiological correlation. J Pediatr Endocrinol Metab 2009;22:921-8.
39. 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;72:456-60; discussion 60.
40. 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;39:307-13.
41. 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;39:451-6.
42. Garel C, Leger J. Contribution of magnetic resonance imaging in non-tumoral hypopituitarism in children. Horm Res 2007;67:194-202.
43. Glezer A, Paraiba DB, Bronstein MD. Rare sellar lesions. Endocrinol Metab Clin North Am 2008;37:195-211, x.
44. Jagannathan J, Kanter AS, Sheehan JP, Jane JA, Jr., Laws ER, Jr. Benign brain tumors: sellar/parasellar tumors. Neurol Clin 2007;25:1231-49, xi.
45. 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;36:335-8.
46. Kumar J, Kumar A, Sharma R, Vashisht S. Magnetic resonance imaging of sellar and suprasellar pathology: a pictorial review. Curr Probl Diagn Radiol 2007;36:227-36.
47. 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;149:759-69; discussion 69.
48. Li G, Shao P, Sun X, Wang Q, Zhang L. Magnetic resonance imaging and pituitary function in children with panhypopituitarism. Horm Res Paediatr 2010;73:205-9.
49. 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;17:1111-4.
50. Lundin P, Bergstrom K, Thuomas KA, Lundberg PO, Muhr C. Comparison of MR imaging and CT in pituitary macroadenomas. Acta Radiol 1991;32:189-96.
51. Maghnie M, Triulzi F, Larizza D, et al. Hypothalamic-pituitary dwarfism: comparison between MR imaging and CT findings. Pediatr Radiol 1990;20:229-35.

52. 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;34:468-75.

53. Mehta A, Hindmarsh PC, Mehta H, et al. Congenital hypopituitarism: clinical, molecular and neuroradiological correlates. Clin Endocrinol (Oxf) 2009;71:376-82.

54. Molitch ME, Gillam MP. Lymphocytic hypophysitis. Horm Res 2007;68 Suppl 5:145-50.

55. Murad-Kejbou S, Eggenberger E. Pituitary apoplexy: evaluation, management, and prognosis. Curr Opin Ophthalmol 2009;20:456-61.

56. 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;149:536-41.

57. Rambaldini GM, Butalia S, Ezzat S, Kucharczyk W, Sawka AM. Clinical predictors of advanced sellar masses. Endocr Pract 2007;13:609-14.

58. Rao VJ, James RA, Mitra D. Imaging characteristics of common suprasellar lesions with emphasis on MRI findings. Clin Radiol 2008;63:939-47.

59. Rennert J, Doerfler A. Imaging of sellar and parasellar lesions. Clin Neurol Neurosurg 2007;109:111-24.

60. Sahdev A, Reznek RH, Evanson J, Grossman AB. Imaging in Cushing's syndrome. Arq Bras Endocrinol Metabol 2007;51:1319-28.

61. Schneider HJ, Aimaretti G, Kreitschmann-Andermahr I, Stalla GK, Ghigo E. Hypopituitarism. Lancet 2007;369:1461-70.

62. Cottier JP, Destrieux C, Brunereau L, et al. Cavernous sinus invasion by pituitary adenoma: MR imaging. Radiology 2000;215:463-9.

63. Micko AS, Wohrer A, Wolfsberger S, Knosp E. Invasion of the cavernous sinus space in pituitary adenomas: endoscopic verification and its correlation with an MRI-based classification. J Neurosurg 2015;122:803-11.

64. Macpherson P, Hadley DM, Teasdale E, Teasdale G. Pituitary microadenomas. Does Gadolinium enhance their demonstration? Neuroradiology 1989;31:293-8.

65. Tripathi S, Ammini AC, Bhatia R, et al. Cushing's disease: pituitary imaging. Australas Radiol 1994;38:183-6.

66. Deipolyi AR, Hirsch JA, Oklu R. Bilateral inferior petrosal sinus sampling. J Neurointerv Surg 2012;4:215-8.

67. 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;45:147-56.

68. 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;32:865-73.

69. Isaacs RS, Donald PJ. Sphenoid and sellar tumors. Otolaryngol Clin North Am 1995;28:1191-229.

70. Bonneville JF, Cattin F, Dietemann JL. Hypothalamic-pituitary region: computed tomography imaging. Baillieres Clin Endocrinol Metab 1989;3:35-71.

71. Carr DH, Sandler LM, Joplin GF. Computed tomography of sellar and parasellar lesions. Clin Radiol 1984;35:281-6.

72. Harrison MJ, Morgello S, Post KD. Epithelial cystic lesions of the sellar and parasellar region: a continuum of ectodermal derivatives? J Neurosurg 1994;80:1018-25.

73. Hershey BL. Suprasellar masses: diagnosis and differential diagnosis. Semin Ultrasound CT MR 1993;14:215-31.

74. Kakite S, Fujii S, Kurosaki M, et al. Three-dimensional gradient echo versus spin echo sequence in contrast-enhanced imaging of the pituitary gland at 3T. Eur J Radiol 2011;79:108-12.

75. Nakazawa H, Shibamoto Y, Tsugawa T, et al. Efficacy of magnetic resonance imaging at 3 T compared with 1.5 T in small pituitary tumors for stereotactic radiosurgery planning. Jpn J Radiol 2014;32:22-9.

76. Hughes JD, Fattahi N, Van Gompel J, Arani A, Ehman R, Huston J, 3rd. Magnetic resonance elastography detects tumoral consistency in pituitary macroadenomas. Pituitary 2016;19:286-92.

77. Heck A, Ringstad G, Fougner SL, et al. Intensity of pituitary adenoma on T2-weighted magnetic resonance imaging predicts the response to octreotide treatment in newly diagnosed acromegaly. Clin Endocrinol (Oxf) 2012;77:72-8.

78. Castillo M. Pituitary gland: development, normal appearances, and magnetic resonance imaging protocols. Top Magn Reson Imaging 2005;16:259-68.

79.   Gao R, Isoda H, Tanaka T, et al. Dynamic gadolinium-enhanced MR imaging of pituitary adenomas: usefulness of sequential sagittal and coronal plane images. Eur J Radiol 2001;39:139-46.

80.   Rand T, Lippitz P, Kink E, et al. Evaluation of pituitary microadenomas with dynamic MR imaging. Eur J Radiol 2002;41:131-5.

81.   Grober Y, Grober H, Wintermark M, Jane JA, Jr., Oldfield EH. Comparison of MRI techniques for detecting microadenomas in Cushing's disease. J Neurosurg 2017:1-7.

82.   Chin BM, Orlandi RR, Wiggins RH, 3rd. Evaluation of the sellar and parasellar regions. Magn Reson Imaging Clin N Am 2012;20:515-43.

83.   Briet C, Salenave S, Bonneville JF, Laws ER, Chanson P. Pituitary Apoplexy. Endocr Rev 2015;36:622-45.

84.   Tosaka M, Sato N, Hirato J, et al. Assessment of hemorrhage in pituitary macroadenoma by T2*-weighted gradient-echo MR imaging. AJNR Am J Neuroradiol 2007;28:2023-9.

85.   Sarwar KN, Huda MS, Van de Velde V, et al. The prevalence and natural history of pituitary hemorrhage in prolactinoma. J Clin Endocrinol Metab 2013;98:2362-7.

86.   Bladowska J, Biel A, Zimny A, et al. Are T2-weighted images more useful than T1-weighted contrast-enhanced images in assessment of postoperative sella and parasellar region? Med Sci Monit 2011;17:MT83-90.

87.   Ziu M, Dunn IF, Hess C, et al. Congress of Neurological Surgeons Systematic Review and Evidence-Based Guideline on Posttreatment Follow-up Evaluation of Patients With Nonfunctioning Pituitary Adenomas. Neurosurgery 2016;79:E541-3.

88.   Kremer P, Forsting M, Ranaei G, et al. Magnetic resonance imaging after transsphenoidal surgery of clinically non-functional pituitary macroadenomas and its impact on detecting residual adenoma. Acta Neurochir (Wien) 2002;144:433-43.

89.   Yoon PH, Kim DI, Jeon P, Lee SI, Lee SK, Kim SH. Pituitary adenomas: early postoperative MR imaging after transsphenoidal resection. AJNR Am J Neuroradiol 2001;22:1097-104.

90.   Coulter IC, Mukerji N, Bradey N, Connolly V, Kane PJ. Radiologic follow-up of non-functioning pituitary adenomas: rationale and cost effectiveness. J Neurooncol 2009;93:157-63.

91.   Kilic T, Ekinci G, Seker A, Elmaci I, Erzen C, Pamir MN. Determining optimal MRI follow-up after transsphenoidal surgery for pituitary adenoma: scan at 24 hours postsurgery provides reliable information. Acta Neurochir (Wien) 2001;143:1103-26.

92.   Parrott J, Mullins ME. Postoperative imaging of the pituitary gland. Top Magn Reson Imaging 2005;16:317-23.

93.   Huang KT, Bi WL, Smith TR, Zamani AA, Dunn IF, Laws ER, Jr. Intrasellar abscess following pituitary surgery. Pituitary 2015;18:731-7.

94.   Ahmadipour Y, Lemonas E, Maslehaty H, et al. Critical analysis of anatomical landmarks within the sphenoid sinus for transsphenoidal surgery. Eur Arch Otorhinolaryngol 2016;273:3929-36.

95.   Chen X, Dai J, Ai L, et al. Clival invasion on multi-detector CT in 390 pituitary macroadenomas: correlation with sex, subtype and rates of operative complication and recurrence. AJNR Am J Neuroradiol 2011;32:785-9.

96.   Eroukhmanoff J, Tejedor I, Potorac I, et al. MRI follow-up is unnecessary in patients with macroprolactinomas and long-term normal prolactin levels on dopamine agonist treatment. Eur J Endocrinol 2017;176:323-28.

97.   Hassan HA, Bessar MA, Herzallah IR, Laury AM, Arnaout MM, Basha MAA. Diagnostic value of early postoperative MRI and diffusion-weighted imaging following trans-sphenoidal resection of non-functioning pituitary macroadenomas. Clin Radiol 2018;73:535-41.

98.   Debeneix C, Bourgeois M, Trivin C, Sainte-Rose C, Brauner R. Hypothalamic hamartoma: comparison of clinical presentation and magnetic resonance images. Horm Res 2001;56:12-8.

99.   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;25:450-62.

100.   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;17:775-80.

101.   Iorgi ND, Allegri AE, Napoli F, et al. The use of neuroimaging for assessing disorders of pituitary development. Clin Endocrinol (Oxf) 2012;76:161-76.

102.   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;88:414-8; discussion 14-8.

103. 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.

104. Carel JC, Eugster EA, Rogol A, et al. Consensus statement on the use of gonadotropin-releasing hormone analogs in children. Pediatrics 2009;123:e752-62.

105. Chung EM, Biko DM, Schroeder JW, Cube R, Conran RM. From the radiologic pathology archives: precocious puberty: radiologic-pathologic correlation. Radiographics 2012;32:2071-99.

106. Choi KH, Chung SJ, Kang MJ, et al. Boys with precocious or early puberty: incidence of pathological brain magnetic resonance imaging findings and factors related to newly developed brain lesions. Ann Pediatr Endocrinol Metab 2013;18:183-90.

107. Kaplowitz PB. Do 6-8 year old girls with central precocious puberty need routine brain imaging? Int J Pediatr Endocrinol 2016;2016:9.

108. Klein DA, Emerick JE, Sylvester JE, Vogt KS. Disorders of Puberty: An Approach to Diagnosis and Management. Am Fam Physician 2017;96:590-99.

109. Mogensen SS, Aksglaede L, Mouritsen A, et al. Pathological and incidental findings on brain MRI in a single-center study of 229 consecutive girls with early or precocious puberty. PLoS One 2012;7:e29829.

110. Pedicelli S, Alessio P, Scire G, Cappa M, Cianfarani S. Routine screening by brain magnetic resonance imaging is not indicated in every girl with onset of puberty between the ages of 6 and 8 years. J Clin Endocrinol Metab 2014;99:4455-61.

111. Rieth KG, Comite F, Dwyer AJ, et al. CT of cerebral abnormalities in precocious puberty. AJR Am J Roentgenol 1987;148:1231-8.

112. Carel JC, Leger J. Clinical practice. Precocious puberty. N Engl J Med 2008;358:2366-77.

113. Oatman OJ, McClellan DR, Olson ML, Garcia-Filion P. Endocrine and pubertal disturbances in optic nerve hypoplasia, from infancy to adolescence. Int J Pediatr Endocrinol 2015;2015:8.

114. American College of Radiology. ACR–SPR Practice Parameter for the Safe and Optimal Performance of Fetal Magnetic Resonance Imaging (MRI). Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/mr-fetal.pdf. Accessed November 30, 2018.

115. American College of Radiology. ACR-SPR Practice Parameter for Imaging Pregnant or Potentially Pregnant Adolescents and Women with Ionizing Radiation. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/pregnant-pts.pdf. Accessed November 30, 2018.

116. American College of Radiology. ACR-ACOG-AIUM-SRU Practice Paramater for the Performance of Obstetrical Ultrasound. Available at: https://www.acr.org/-/media/ACR/Files/Practice-Parameters/us-ob.pdf. Accessed November 30, 2018.

117. American College of Radiology. *Manual on Contrast Media*. Available at: https://www.acr.org/Clinical-Resources/Contrast-Manual. Accessed November 30, 2018.

118. Kanal E, Barkovich AJ, Bell C, et al. ACR guidance document on MR safe practices: 2013. J Magn Reson Imaging 2013;37:501-30.

119. American College of Radiology. ACR Appropriateness Criteria® Radiation Dose Assessment Introduction. Available at: https://www.acr.org/-/media/ACR/Files/Appropriateness-Criteria/RadiationDoseAssessmentIntro.pdf. Accessed November 30, 2018.