CE 2.5 ANCC Contact Hours

Managing the Patient With Transsphenoidal Pituitary Tumor Resection

Wen Yuan

ABSTRACT

Patients who undergo transsphenoidal pituitary tumor resection require a multidisciplinary team approach, consisting of a neurosurgeon, an endocrinologist, and nurses. Successful transsphenoidal surgery needs expert nursing care for early identification and prompt treatment of pituitary dysfunction and neurosurgical complications. Pituitary dysfunction includes adrenal insufficiency, diabetes insipidus, syndrome of inappropriate antidiuretic hormone, and cerebral salt wasting syndrome. Neurosurgical complications may include visual disturbance, cerebrospinal fluid leak, subdural hematoma, and epistaxis.

Keywords: CSW, DI, endocrinological complications, neurosurgical complications, SIADH, transsphenoidal pituitary tumor resection

Pituitary tumors account for 10%–15% of brain neoplasms and are usually benign neoplasms of epithelial pituitary tissue (Muh & Oyesiku, 2008). Nonfunctional pituitary tumors may result in varying degrees of hypopituitarism or progressive bitemporal visual field loss; hormone-secreting pituitary tumors cause pathological syndromes such as acromegaly, Cushing disease (hypercortisolism), and thyrotoxicosis. Furthermore, the growth of a pituitary tumor affects adjacent brain structures, causing neurological deficits such as visual disturbance (Barkan, Blank, & Chandler, 2008). The incidence of surgical complications after transsphenoidal (TS) surgery for pituitary lesions is low if surgery is performed by an experienced neurosurgeon (Ausiello, Bruce, & Freda, 2008). The most common complication is diabetes insipidus (DI), especially in patients with pituitary microadenomas and Cushing disease. Other complications include adrenal insufficiency, syndrome of inappropriate antidiuretic hormone (SIADH), cerebral salt wasting syndrome (CSW), and neurosurgical complications such as vision loss, cerebral spinal fluid (CSF) leak, subdural hematoma, and epistaxis (Ausiello et al., 2008). The purpose of this article is to help nurses to understand the physiology of the pituitary gland and the importance of early identification and prompt treatment of postoperative complications and to familiarize them with instructions regarding discharge. These measures will shorten hospital stays and reduce healthcare expenditures while enhancing successful TS pituitary surgery and quality of life.

Literature Search Methods

PubMed, CINAHL, Ovid, and textbooks were searched using the search terms ‘‘postoperative care following transsphenoidal pituitary surgery,’’ ‘‘nursing care and transsphenoidal pituitary tumor surgery,’’ ‘‘glucocorticoids replacement in pituitary surgery,’’ and ‘‘glucose detection in cerebrospinal fluid leak.’’ To be more comprehensive, the following key words were also used in finding more relevant articles: ‘‘pituitary,’’ ‘‘pituitary surgery,’’ ‘‘transsphenoidal surgery,’’ ‘‘diabetes insipidus,’’ and ‘‘syndrome of inappropriate antidiuretic hormone.’’ The inclusion criteria were set to limit the search to articles from peer-reviewed scholarly journals and textbooks written in English from 1998 to 2011 that related to postoperative care after TS pituitary tumor surgery, including prospective observational studies, systematic reviews, and chapters from textbooks. Articles from nonscholarly sources or commercial health information sites were excluded. A total of 17 articles were found to be eligible under the inclusion criteria and most relevant to the topic. Of the 17 articles, under ‘‘postoperative care following transsphenoidal pituitary surgery,’’ only three articles met inclusion criteria and addressed SIADH and DI, water and electrolyte metabolism disturbances, and management after pituitary tumor surgery. Under ‘‘glucocorticoid replacement in pituitary surgery,’’ the three articles were found to be relevant based on the search criteria discussed assessment and management of hypothalamic–pituitary–adrenal (HPA) axis dysfunction. Under ‘‘glucose detection in cerebrospinal fluid leak,’’ one article published in 2004 assessed the usefulness of glucose detection in diagnosing

Questions or comments about this article may be directed to Wen Yuan, RN ACNP-C MSN, at wendyla3@gmail.com. She is an Acute Care Nurse Practitioner at Kaiser Permanente Foundation Hospitals, Los Angeles Medical Center, Los Angeles, CA.

The author declares no conflicts of interest.

DOI: 10.1097/JNN.0b013e3182828e28

cerebrospinal fluid (CSF) leak. Only two recent articles in the nursing literature met the inclusion criteria under ''nursing care and transsphenoidal pituitary tumor surgery.'' Eisenberg and Redick (1998) explored a critical pathway as a tool in identifying and managing the two most common potential complications (DI and CSF rhinorrhea) after TS pituitary tumor resection. Prather, Forsyth, Russell, and Wagner (2003) discussed the successful program at the University of Virginia, which mainly consisted of preoperative nursing assessment, patient education, nursing care issues as well as complications monitoring (DI and CSF leak), laboratory follow-up (e.g., serum cortisol level), and staff education in caring for the patient undergoing TS surgery. One significant finding of this search was the revelation that there is limited literature addressing the importance of frontline nursing management in the early postoperative period of TS pituitary surgery. Such management would be expected to have a positive impact on the prompt treatment of potentially life-threatening complications. Furthermore, there are few articles that emphasize the importance of knowledge-based nursing education pertaining to the physiology and pathophysiology of the pituitary gland, which, if corrected, would serve to empower nurses in science-based practice and provide safe, quality patient care.

Frontline nursing management is critical in assuring quality care and optimal patient outcomes for individuals who have undergone transphenoidal pituitary tumor resection.

Physiology of the Pituitary

The pituitary, a small but important endocrine gland acting as the ''conductor of the endocrine orchestra'' (Ben-Shalomo & Melmed, 2011), is located at the base of the brain. It is connected to the hypothalamus by the pituitary stalk and is divided into two parts, the anterior and posterior. Its release of hormones is controlled by the hypothalamus (Bougle & Annane, 2009). The anterior pituitary gland or adenohypophysis originates embryologically from Rathke's pouch and produces six hormones (Drouin, 2011), including luteinizing hormone, follicle-stimulating hormone, prolactin, growth hormone, adrenocorticotropic hormone (ACTH), and thyroid-stimulating hormone (Table 1).

TABLE 1. Hormones Produced by the Pituitary Gland (Matfin, 2009)

Hormone	Major Organs	Major Physiologic Effects
Anterior pituitary gland		
Growth hormone	Liver and adipose tissue	Stimulates growth of bone and muscle
		Promotes protein synthesis and metabolism
		Decreases carbohydrate metabolism
Thyroid-stimulating hormone	Thyroid gland	Stimulates synthesis of secretion of thyroid hormone
Adrenocorticotropic hormone	Adrenal cortex	Stimulates synthesis and secretion of adrenal cortical hormone
Prolactin	Mammary gland	Stimulates female breast to produce milk
Luteinizing hormone	Ovaries and testis	Females: stimulates corpus luteum development, oocyte release, and estrogen and progesterone production
		Males: stimulates testosterone secretion and interstitial testes development
Follicle-stimulating hormone	Ovaries and testis	Females: stimulates ovarian maturation and ovulation
		Males: stimulates sperm production
Posterior pituitary gland		
Antidiuretic hormone	Renal collecting tubules	Stimulates renal tubule to reabsorb water
Oxytocin	Ovaries	Stimulates uterine contractions and production of milk after birth

The posterior pituitary gland or neurohypophysis secretes antidiuretic hormone (ADH) and oxytocin (Table 1).

Postoperative Care

There are two postoperative phases of TS surgery, including the early phase, which ranges from immediately after surgery to several weeks thereafter, and the later phase. This article will focus on the early postoperative phase. In the early postoperative phase, assessing anterior and posterior pituitary dysfunction is a high priority that includes monitoring pituitary–adrenal axis, DI, SIADH, and cerebral salt waste syndrome (CSW). In addition, nurses need to carefully monitor for neurosurgical complications (Table 2).

Assessing HPA Axis

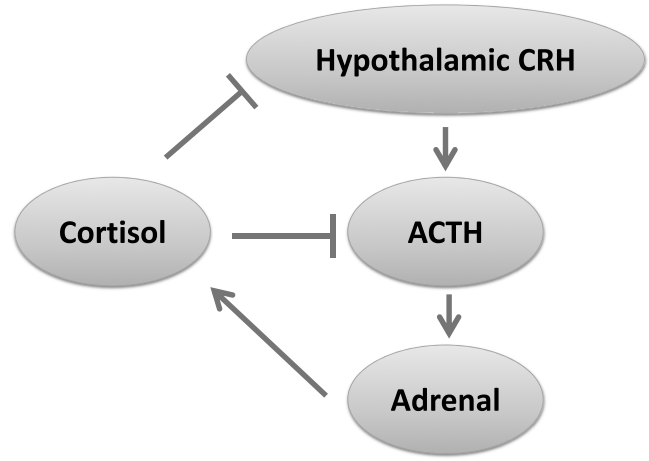
It is important for nurses to understand the reason to assess HPA axis function. Under normal conditions, the HPA axis has a complex negative feedback between hypothalamus, pituitary, and adrenal cortex (Figure. 1). The hypothalamus produces corticotropic hormone, which stimulates corticotrophs to release ACTH, which then stimulates the adrenal cortex to produce and release cortisol and androgens. Cortisol in turn inhibits further release of both corticotropic hormone and ACTH. Cortisol plays a crucial role in controlling the body's stress response and regulating cardiovascular function, digestion, metabolism, the immune system, body temperature, mood, sex drive, behavior, and cognition (Aron, Findling, & Tyrrell, 2007). Therefore, the perioperative and postoperative assessment of the HPA axis is extremely important, since lack of cortisol can lead to acute adrenal insufficiency, which may be a life-threatening condition. Clinical features of adrenal insufficiency may include extreme weakness, fatigue, myalgia, altered mental status, hypotension, hyponatremia, hypoglycemia, headache, anorexia, nausea, and vomiting (Aron et al., 2007).

Patients with pituitary tumors may undergo a 250-µg cosyntropin stimulation test or a cortisol level check before surgery to assess pituitary–adrenal function. Glucocorticoids must be replaced if there is preoperative cortisol deficiency (Inder & Hunt, 2002). However, most patients with a sizable pituitary lesion are at risk for hypoadrenalism (Ben-Shalomo & Melmed, 2011); therefore, a prophylactic stress dose of glucocorticoid, hydrocortisone (100 mg), is usually given intravenously during the immediate perioperative period of TS surgery except for patients with Cushing disease (Barkan et al., 2008). In most hospitals, routine administration of stress doses of glucocorticoids, either hydrocortisone or dexamethasone, to all TS surgical patients continues for 48–72 hours starting right before surgery and is then quickly weaned off (Ausiello et al., 2008). Administration of stress doses of glucocorticoids protects against possible impairment of ACTH secretion because of manipulating and exploration of the anterior pituitary, the stalk, or the hypothalamus. Hydrocortisone is commonly chosen because of its shorter half-life and lesser HPA axis suppression. However, dexamethasone (2 mg iv) may also be administrated at the time of surgery and 1 mg intravenous (IV) twice a day after surgery. Its advantage is in not interfering with serum determinations of cortisol levels; however, it does have HPA axis suppressive effects (Ausiello et al., 2008).

TABLE 2. Assessment of Early Postoperative Transsphenoidal Pituitary Surgery (Ausiello et al., 2008)

Screen	Monitoring
Hypothalamic–pituitary–adrenal axis	Serum cortisol level
	Cosyntropin stimulation test
Diabetes insipidus	Fluid intake and hourly urine output
	Serum electrolytes, serum osmolality, urine sodium, urine osmolality, and urine specific gravity
Syndrome of inappropriate diuretic hormone secretion	Fluid intake and urine output
	Serum sodium, serum osmolality, urine sodium, urine osmolality, and urine specific gravity
Neurosurgical complications	Visual loss
	Cerebrospinal fluid rhinorrhea
	Meningitis
	Subdural hematoma
	Epistaxis

FIGURE 1 Regulation of Cortisol Secretion (Wang & Majzouh, 2011)



Special attention is needed from nurses to make sure morning serum cortisol levels on postoperative days 2 and 3 are drawn so that physicians can assess HPA axis integrity and determine the necessity of continuing oral hydrocortisone after discharge. If the cortisol level is less than 270.6 nmol/L (10 μg/dl) on the morning of the second day after TS surgery, patients are discharged with low-dose oral hydrocortisone, usually 15 mg in the morning before breakfast and 5 mg in the evening right after dinner. The patient is instructed to recheck a morning cortisol level 1 week after discharge without taking hydrocortisone within the prior 24 hours (Ausiello et al., 2008). When discharging a post TS surgical patient without cortisol treatment, the nurse needs to teach the patient to report flu-like symptoms, which may signal possible hypocortisolemia or hyponatremia (Prather et al., 2003).

Monitoring DI

ADH is synthesized by neurons of the supraoptic and paraventricular nuclei of the hypothalamus and stored in the posterior pituitary gland. Once ADH is released into the circulation, it acts on V2 receptor of renal collecting tubules to facilitate the passive reabsorption of water (Bougle & Annane, 2009). In the early postoperative period of TS pituitary surgery, DI is the most commonly encountered complication and is likely because of impaired ADH secretions caused by the manipulation and/or vascular alterations of the hypothalamus and posterior lobe of the pituitary gland during surgery (Kristof, Rother, Neuloh, & Klongmuler, 2009). DI incidence is low when TS surgery is performed by an experienced neurosurgeon. Most DI is a transient phenomenon beginning within 24–48 hours after surgery and resolving in 72 hours when vasopressin secretions recover (Dumont, Nemergut, Jane, & Laws, 2005). However, in some cases, patients may also develop biphasic and triphasic patterns of DI. In a biphasic pattern, DI is followed by hyponatremia, especially seen among patients who undergo 1-deamino-8-d-arginine vasopressin (desmopressin acetate [DDAVP]) therapy for transient DI (Ausiello et al., 2008). In a triphasic pattern, DI is followed by hyponatremia and then DI reappears thereafter, and this condition usually is a sign of a permanent damage to the neurons in the hypothalamus (Kristof et al., 2009). DI can be dangerous if fluid and electrolyte imbalances are not corrected immediately. The nurse needs to identify early signs and symptoms of dehydration, hypernatremia, and hypokalemia to initiate treatment quickly by following critical pathways per individual institutional standard for TS pituitary surgery.

DI manifests as polyuria, polydipsia, fever, excessive thirst, hypovolemia, and hypotension. The patient often produces a large amount of diluted urine, as much as 2.5 L/day and even up to 4–18 L/day, because of an inability to concentrate urine. As a result, urine-specific gravity, sodium, and osmolality are low, whereas serum sodium and osmolality are high (Table 3). DI is typically treated when urine output is greater than 250 ml/hour for 2–3 consecutive hours, urine-specific gravity is less than 1.005, serum sodium is greater than 145 mEq/L, and serum osmolality is greater than 295 mOsm/L (Eisenberg & Redick, 1998). When treating DI, the standard routine at most institutions is to check serum electrolytes and urine-specific gravity every 4 hours until stable and to give DDAVP, a synthetic analog of ADH, at 1–2 μg (iv or sc), as needed along with oral and intravenous fluid replacement (Barkan et al., 2008). Nurses must make sure the patient has free access to oral fluid and carefully monitor urine output, urine-specific gravity, urine osmolality, serum sodium level, serum osmolality, and mental status.

TABLE 3. Comparison of DI and SIADH (Barkley, 2008a, 2008b)

	Diabetes Insipidus	Syndrome of Inappropriate Antidiuretic Hormone
Urine output	Polyuric	Decreased
Urine pH	Low, <1.005	High, >1.020
Urine sodium	Low, < 20 mmol/L	High, > 20 mmol/L
Urine osmolarity	Low, < 300 mOsm/L	High, > 310 mOsm/L
Serum sodium	High, >145 mEq/L	Low, < 135 mEq/L
Serum osmolarity	High, > 295 mOsm/L	Low, < 270 mOsm/L
CVP	Low	High

Monitoring SIADH and CSW

SIADH is the most common cause of hypotonic hyponatremia in the TS pituitary surgical patients. Whereas absent or deficient ADH will cause DI, excessive release of ADH will result in SIADH. Postoperative SIADH occurs most commonly on postoperative day 9 or later, when the patient has already been discharged to home. Its pathology is not well understood, but it carries a higher risk of mortality than DI (Kristof et al., 2009). It clinically manifests as low urine output and extremely concentrated urine despite adequate fluid intake. SIADH is either euvolemic or mildly hypervolemic (Barkan et al., 2008). Laboratory values typically show high urine-specific gravity, urine sodium, and urine osmolality but low serum sodium and osmolality (Table 3). SIADH incidence is higher after receiving DDAVP for transient DI (Ausiello et al., 2008). The most common signs and symptoms of SIADH include headache, agitation, nausea, vomiting, lethargy, apathy, disorientation, muscle cramps, and anorexia. When serum sodium is extremely low (less than 120 mEq/L), the patient is at high risk for seizures and even coma. Therefore, severe hyponatremia requires progressive treatment with hypertonic solution such as 3% sodium chloride intravenous infusion, frequent electrolyte checks, and fluid-intake restriction. In general, a strict fluid-intake restriction to 1 L/day for serum Na^+ (≤30 mmol/L) and 500 ml/day for serum Na^+ (≤125 mmol/L) is necessary. In most mild hyponatremia cases, fluid-intake restriction is sufficient because of patient's own compensating capacity (Kristof et al., 2009). Nurses can use their knowledge to educate the patient about fluid and electrolyte balance when discharging the patient to home.

CSW has similar laboratory findings to SIADH but is less commonly seen after TS pituitary surgery. Its signs include hyponatremia, elevated ADH, decreased urine sodium, and low urine output (Dumont et al., 2005). However, there is a principal difference between SIADH and CSW: Patients with CSW are usually volume depleted, as opposed to euvolemic or hypervolemic, and these patients are treated with normal saline intravenous infusion. Therefore, it is important for nurses to observe and document intake and output correctly. Central lines and sometimes Swan-Ganz catheterization and further laboratory studies (e.g., blood urea nitrogen, creatinine, and brain natriuretic peptide) may be needed to monitor fluid status and differentiate these two disorders in clinical practice (Barkan et al., 2008).

Monitoring Neurosurgical Complications

There are also direct neurosurgical complications other than the above endocrinological complications that may follow TS pituitary surgery. The nurse will need to perform the same neurological assessment as with any other craniotomy. TS surgery approaches a tumor that sits below and often compresses the optic nerves. Therefore, it is critical to check visual acuity, visual fields, and extraocular movements every hour in the first 24 hours post TS surgery (Ausiello et al., 2008). Second, CSF leak may occur if the tumor or its removal violates the layer of dura lying above the pituitary gland, known as the diaphragma sellae. This happens more frequently with resection of large pituitary tumors (Dumont et al., 2005). After TS surgery, nurses monitor closely and teach the patient to report any excessive clear fluid drainage from the nose, particularly when the patient bends over, as this may represent CSF rhinorrhea. Suspected CSF rhinorrhea needs to be reported to the neurosurgeon immediately and treated as soon as possible to prevent meningitis. Intraoperative CSF rhinorrhea is closely associated with postoperative meningitis, and such patients may have the signs and symptoms of severe headache, fever, sensitivity to light, persistent nasal discharge, and meningismus (Dumont et al., 2005). CSF rhinorrhea frequently drains posteriorly, especially when the patient's nose is packed in the immediate postoperative period, and patients may report having a salty or bitter taste in their mouth. CSF rhinorrhea may be

difficult to detect as it manifests as a clear, colorless, and odorless nasal discharge in the immediate postoperative period; in addition, it can be quickly absorbed by ''moustache'' dressing (Prather et al., 2003). Traditional glucose test strips are no longer recommended as a confirmatory test for CSF rhinorrhea because they lack specificity and sensitivity. When the nature of the fluid is uncertain, especially in a postoperative inpatient setting in which no CSF was encountered during surgery, sending nasal drainage to the laboratory for immunofixation electrophoresis (which can detect beta-2 transferrin, a protein found in the brain and CSF, but not in normal nasal mucosal secretions) is reported to have high sensitivity and specificity to confirm CSF rhinorrhea. Furthermore, a computed tomography scan of brain can also assist in diagnosing CSF rhinorrhea (Chan, Poon, IP, Chiu, & Goh, 2004). Treatment of CSF rhinorrhea consists of bed rest, lumbar spinal drainage, antibiotics, and, in certain instances, surgical repair of the leakage site with a graft of fat or fascia (Dumont et al., 2005). Third, epistaxis may be seen postoperatively after nasal packing is removed. This generally originates in the nasal mucosa and most often resolves spontaneously or with topical application of oxymetazoline, but because of the proximity of pituitary tumors to the carotid arteries and cavernous sinuses, epistaxis must be reported to the neurosurgeon immediately (Ausiello et al., 2008).

The TS surgical patient typically stays in the intensive care unit for the first 24 hours post TS surgery. Headache is a major complaint after TS surgery, and the nurse may give narcotics, such as intravenous morphine, as needed. Nasal packing is usually removed on the second or third day after surgery, and this procedure may be uncomfortable for the patient. Whereas modern TS surgery is usually often performed using a direct transnasal route, in some cases the incision is made under the lip. In these patients, performing oral care every 4 hours may help to prevent suture line infection. In addition, applying a humidified oxygen mask to keep optimal oxygen saturation and facilitate easy breathing by mouth may make the patient less uncomfortable. The nurse should monitor for sleep apnea (especially for the patient with acromegaly), teach the patient not to blow the nose, use an incentive spirometer, cough hard, or sneeze forcefully through the nose due to risk of dislodging the surgical repair or forcing air into inflamed sinuses. ''Moustache'' dressings placed under nose and held by nonadhesive tape can be changed as needed (Prather et al., 2003). The TS surgical patient should be encouraged to get out of bed to walk on postoperative day 1 and is usually discharged on the third day after surgery if there are no complications. However, patients who undergo a TS skull base approach to sellar and parasellar tumors are managed slightly different because these patients may have lumbar drains for 48–72 hours after surgery (Dumont et al., 2005).

Discharge Instructions

Discharge instructions are provided in written and verbal format. Before discharge, the nurse will need to spend time with the patient to review, reinforce, and ask for a return demonstration of understanding of home care instructions. Typically, TS patients are seen by their neurosurgeons a few weeks after discharge to check wound healing and by their endocrinologist in 6 weeks for hormone assessment and replacement therapy. At the 6-week appointment, all pituitary hormones such as serum cortisol, prolactin, thyroid stimulating hormone, triiodothyronine (T3), thyroxine (T4), follicle stimulating hormone, luteinize hormone, somatomedin C (IGF-1), and testosterone will be checked by the endocrinologist. It is important to emphasize to the patient the rationale for follow-up with the endocrinologist. Three months following TS surgery, the patient will usually have magnetic resonance imaging of sella turcica and follow-up with the neurosurgeon done. Afterwards, magnetic resonance imaging of brain is typically performed annually or at the neurosurgeon's preference to follow up for residual pituitary tumor or recurrence. Before the appointment, the patient needs to be instructed to report signs and symptoms discussed previously of hypopituitarism, DI, SIADH, CSW, CSF rhinorrhea, infections, and any other illness. The patient also needs to be advised not to lift weight over 20 pounds over the first 4 weeks post TS surgery and to refrain from underwater diving and bungee jumping that may place pressure on the sinuses (Prather et al., 2003). Air travel is usually avoided during this period, as sinus inflammation following surgery may make it difficult for the patient to equalize pressure (e.g., make the ears pop). Clear discharge instruction enables the patient to monitor for complications and promote a smooth recovery process.

Conclusion

The complications of TS pituitary tumor resection are rare, but potentially serious and even life threatening if not treated promptly (Ausiello et al., 2008). It is necessary for nurses to understand the importance of early identification and treatment of HPA axis dysfunction, DI, SIADH, and other neurosurgical complications. Nurses must understand the basic physiology and pathophysiology of the pituitary gland; furthermore, critical pathways designed to assess and treat endocrinological and neurosurgical complications of

pituitary tumors must be in place. Successful pituitary surgery is achieved by a rigorous team effort including the neurosurgeon, endocrinologist, and nurse. The importance of expert knowledge and superior nursing care cannot be understated when caring for the TS surgical patients.

References

Aron, D. C., Findling, J. W., & Tyrell, J. B. (2007). Glucocorticoids and adrenal androgens. In D. G. Gardner, & D. Shoback (Eds.), *Greenspan's basic and clinical endocrinology* (8th ed., pp. 371). New York, NY: McGraw-Hill.

Ausiello, J. C., Bruce, J. N., & Freda, P. U. (2008). Postoperative assessment of the patient after transsphenoidal pituitary surgery. *Pituitary*, *11*, 391–401. doi:10.1007/s11102-008-0086-6

Barkan, A. L., Blank, H., & Chandler, W. F. (2008). Pituitary surgery: Peri-operative management. In B. Swearingen, & B. M. K. Biller (Eds.), *Diagnosis and management of pituitary disorders* (pp. 303–319). Totowa, NJ: Humana Press.

Barkley, T. W. Jr. (2008a). Diabetes insipidus. In T. W. Barkley, Jr., & C. M. Myers (Eds.), *Practice guidelines for acute care nurse practitioners* (2nd ed., pp. 487–489). St. Louis, MO: Elsevier.

Barkley, T. W. Jr. (2008b). Syndrome of inappropriate antidiuretic hormone. In T. W. Barkley, Jr., & C. M. Myers (Eds.), *Practice guidelines for acute care nurse practitioners* (2nd ed., pp. 490–492). St. Louis, MO: Elsevier.

Ben-Shlomo, A., & Melmed, S. (2011). Pituitary development. In S. Melmed (Ed.), *The pituitary* (3rd ed., pp. 21–41). San Diego, CA: Elsevier.

Bougle, A., & Annane, D. (2009). Endocrinopathy in the intensive care unit. In A. Gabrielli, A. J. Layon, & M. Yu (Eds.), *Givetta, Taylor, & Kirby's critical care* (4th ed., pp. 2411–2422). Philadelphia, PA: Lippincott William & Wilkins.

Chan, D. T., Poon, W. S., IP, C. P., Chiu, P. W., & Goh, K. Y. (2004). How useful is glucose detection in diagnosing cerebrospinal fluid leak? The rational use of CT and beta-2 transferrin assay in detection of cerebrospinal fluid fistula. *Asian Journal of Surgery*, *27*(1), 39–42. doi:10.1016/S1015-9584(09)60242-6

Drouin, J. (2011). Pituitary development. In S. Melmed (Ed.), *The pituitary* (pp. 3–6). London, United Kingdom: Elsevier.

Dumont, A. S., Nemergut, E. C. II, Jane, J. Jr., & Laws, E. R. Jr. (2005). Postoperative care following pituitary surgery. *Journal of Intensive Care Medicine*, *20*, 127–140. doi:10.1177/0885066605275247

Eisenberg, A. A., & Redick, E. L. (1998). Transsphenoidal resection of pituitary adenoma: Using a critical pathway. *Dimensions of Critical Care Nursing*, *17*(6), 306–312. Retrieved from http://www.springnet.com

Inder, W. J., & Hunt, P. J. (2002). Glucocorticoid replacement in pituitary surgery: Guidelines for perioperative assessment and management. *The Journal of Clinical Endocrinology and Metabolism*, *87*(6), 2745–2750. doi:10.1210/jc.87.6.2745

Kristof, R. A., Rother, M., Neuloh, G., & Klongmuler, D. (2009). Incidence, clinical manifestations, and course of water and electrolyte metabolism disturbances following transsphenoidal pituitary adenoma surgery: A prospective observational study. *Journal of Neurosurgery*, *111*, 555–562. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/19199508

Matfin, G. (2009). Mechanism of endocrine control. In C. M. Porth, & G. Matfin (Eds.), *Pathophysiology* (8th ed., pp. 1010). Philadelphia, PA: Lippincott William & Wilkins.

Muh, C. R., & Oyesiku, N. M. (2008). Non-functioning adenomas: Diagnosis and treatment. In B. Swearingen, & B. M. K. Biller (Eds.), *Diagnosis and management of pituitary disorders* (Eds., pp. 303–319). Totowa, NJ: Humana Press.

Prather, S. H., Forsyth, L. W., Russell, K. D., & Wagner, V. L. (2003). Transsphenoidal surgery in the acute care settings: An alternative to critical care. *Journal of Neuroscience Nursing*, *35*(5), 270–275. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/14593938

Wang, O., & Majzouh, J. A. (2011). Adrenocorticotropin. In S. Melmed (Ed.), *The pituitary* (pp. 56). London, United Kingdom: Elsevier.

Instructions for Taking the CE Test:

- Read the article. The test for this CE activity can be taken online at www.NursingCenter.com/CE/JNN.
- There is only one correct answer for each question. A passing score for this test is 13 correct answers. If you pass, you can print your certificate of earned contact hours and the answer key. If you fail, you have the option of taking the test again at no additional cost.
- If you prefer to mail in the test, access it and the enrollment form at www.JNNOnline/CE. Print the enrollment form and mail it with payment to the address listed. You will receive your earned CE certificate in 4 to 6 weeks.
- Visit www.nursingcenter.com for other CE activities and your personalized CE planner tool.
- For questions or rush service options, contact Lippincott Williams & Wilkins: 1-800-787-8985.

Registration Deadline: April 30, 2015

Disclosure Statement:
The author and planners have disclosed that they have no financial relationships related to this article.

Provider Accreditation:
Lippincott Williams & Wilkins, publisher of *Journal of Neuroscience Nursing*, will award 2.5 contact hours for this continuing nursing education activity.

Lippincott Williams & Wilkins is accredited as a provider of continuing nursing education by the American Nurses Credentialing Center's Commission on Accreditation.

This activity is also provider approved by the California Board of Registered Nursing, Provider Number CEP 11749 for 2.5 contact hours. Lippincott Williams & Wilkins is also an approved provider of continuing nursing education by the District of Columbia and Florida CE Broker #50-1223. Your certificate is valid in all states.

The ANCC's accreditation status of Lippincott Williams & Wilkins Department of Continuing Education refers only to its continuing nursing educational activities and does not imply Commission on Accreditation approval or endorsement of any commercial product.

Payment and Discounts:

- The registration fee for this test is $24.95.
- AANN members – For free CE (online only), members can take the test by logging into the secure "Members Only" area of http://www.aann.org to get the discount code. Use the code when payment is requested when taking the CE test at NursingCenter.com/CE/JNN.
- We offer special discounts and institutional bulk discounts for multiple tests. Call 1-800-787-8985

The CE test for this article is available online only. Log onto the journal website, www.JNNONline.com, or to www.NursingCenter.com/CE/JNN to access the test. For additional continuing education articles related to Neurological topics, go to www.NursingCenter.com/CE.