30-Day Readmissions and Coordination of Care Following Endoscopic Transsphenoidal Pituitary Surgery: Experience with 409 Patients

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J Neurol Surg B Skull Base 2022;83(suppl S2):e410–e418.

Abstract

Objective The study aimed to (1) quantify readmission rates and common causes of readmission following endoscopic transsphenoidal pituitary surgery (ETPS); (2) identify risk factors that may predict readmission within 30 days; (3) assess postoperative care coordination with endocrinology follow-up; and (4) identify patients for whom targeted interventions may reduce 30-day readmissions.

Methods Retrospective quality improvement review of patients with pituitary adenoma who underwent ETPS from December 2010 to 2018 at a single tertiary care center.

Results A total of 409 patients were included in the study, of which 57 (13.9%) were readmitted within 30 days. Hyponatremia was the most common cause of readmission (4.2%) followed by pain/headache (3.9%), cerebrospinal fluid leak (3.4%), epistaxis (2.7%), hypernatremia (1.2%), and adrenal insufficiency (1.2%). Patients with hyponatremia were readmitted significantly earlier than other causes (4.3 ± 2.2 vs. 10.6 ± 10.9 days from discharge, $p = 0.032$). Readmitted patients had significantly less frequent outpatient follow-up with an endocrinologist than the nonreadmitted cohort (56.1 vs. 70.5%, $p = 0.031$). Patients who had outpatient follow-up with an endocrinologist were at lower risk of readmission compared with those without (odds ratio: 0.46; 95% confidence interval: 0.24–0.88).

Conclusion Delayed hyponatremia is one of the most common causes of 30-day readmission following ETPS. Postoperative follow-up with an endocrinologist may reduce risk of 30-day readmission following ETPS.

Keywords
- readmissions
- transsphenoidal surgery
- pituitary surgery
- risk factors
- endocrinology
- coordination of care

received
July 12, 2020
accepted after revision
March 26, 2021
published online
May 25, 2021

DOI https://doi.org/10.1055/s-0041-1729980.
ISSN 2193-6331.

Implications for Clinical Practice A multidisciplinary team incorporating otolaryngologist, neurosurgeons, and endocrinologist may identify patients at risk of 30-day readmissions. Protocols checking serum sodium within 1 week of surgery in conjunction with endocrinologist to tailor fluid restriction may reduce readmissions from delayed hyponatremia.

Introduction

The Center for Medicare and Medicaid Services (CMS) has identified 30-day readmission rates as an important measure of health care quality.[1] The Hospital Readmissions Reduction Program, part of the Affordable Care Act, has begun reducing payments to hospitals with excess readmissions. With recent expansions of readmission measures and reimbursement penalties to surgical procedures, it has become essential to analyze and monitor unplanned readmissions as a quality metric and a performance-related reimbursement optimization method.

Endoscopic endonasal transsphenoidal surgery (ETS) has become a very common procedure to address pathology involving the sella and parasellar skull base.[2,3] Lesions of the pituitary gland are the most common indication for ETS.[3–8] Complications following endoscopic transsphenoidal pituitary surgery (ETPS) are unique due to risk related to both surgical complications and metabolic derangements.[5,9,10] Thus, perioperative management of patients undergoing surgery for pituitary tumors requires a multidisciplinary team of otolaryngologist, neurosurgeons, and endocrinologist.[11,12]

Prior studies have identified 30-day unplanned readmission rates for ETPS to be 4.6 to 11.9%.[9,13–20] Common complications include epistaxis, cerebrospinal fluid (CSF) leak, meningitis, intracranial bleed, pneumocephalus, electrolyte abnormalities, adrenal insufficiency, deep venous thrombosis, pulmonary embolism, and reoperation.[9,10,13–15,21,22]

While hypernatremia due to diabetes insipidus is commonly seen in the immediate postoperative period, delayed hyponatremia has been reported as one of the most common causes of readmission following ETPS.[15,20,22–24] Isolated hyponatremia occurs in up to 25% of patients postoperatively. Symptomatic hyponatremia can occur in up to 13.8% of patients and reaches a nadir on postoperative day (POD) 7.[16,22,24–29] Retrospective studies have linked various demographic, operative variables, and patient comorbidities to delayed hyponatremia; however, there is no agreement on reliability of factors associated with hyponatremia.[25]

Due to the metabolic changes that take place following pituitary surgery, a multidisciplinary team including an endocrinologist may help identify and manage patients with early manifestations of hyponatremia to reduce readmissions.[12,30] However, high volume tertiary referral centers with large referral patterns often require complex coordination of postoperative care between the primary surgeons and referring endocrinologist. These barriers to care may predispose to excess readmissions following ETPS. Therefore, it is important to understand how these unique characteristics affect postoperative care and how they may contribute to readmission.

The goals of this study are to (1) quantify readmission rates following ETPS; (2) identify the common causes of readmission and when they occur relative to surgery; (3) identify risk factors that may predict readmission within 30 days; (4) assess postoperative care coordination with endocrinology follow up; and (5) and identify patients for whom targeted interventions may reduce 30-day readmission.

Methods

Study Design

This is a single institution quality improvement review of all patients with pituitary adenoma who underwent ETPS from December 2010 to 2018. Data were abstracted from the electronic health record (EHR) system developed by Epic Systems (Epic Systems Corporation, Madison, Wisconsin, United States). Variables included patient demographics (age, sex, race, and body mass index (BMI), clinical variables (admission date, surgical date, discharge date, postoperative variables, complications, causes of readmission, and comorbidities), operative variables (tumor size, skull base repair, and intraoperative findings), and outpatient visit patterns. International Classification of Disease (ICD) diagnosis and procedural codes pertaining to the index and readmission inpatient stay were extracted for analysis and comparison.

Patients were included in the study if they were (1) >18 years of age at the time of surgery, (2) had either ICD-10 D35.2 or ICD-9 227.0 diagnosis code, and (3) ICD-10 procedural code 62165.

Variables and Definitions

Readmission refers to 30-day unplanned hospital readmission from all causes following discharge from the indexed inpatient stay. Reasons for readmission were classified as either "medical" or "surgical." Medical causes of readmission were hyponatremia, hypernatremia, pain/headache, and adrenal insufficiency. Surgical causes were CSF leak and epistaxis. Adenomas were classified as either nonfunctioning or functioning depending on secretory characteristics based on preoperative laboratory analyses and permanent pathology on the tumor specimen. Radiologic data were used to characterize extrasellar extension (ESE) and largest tumor size in a single dimension. Intraoperative CSF leaks were classified as either (1) "no leak" (absence of CSF leak confirmed by Valsalva maneuver), (2) "low-flow leak" (confirmed by Valsalva with small diaphragmatic defect), or (3) "high-flow leak" (moderate or large CSF leak

usually with large diaphragmatic defect or opening of the arachnoid).[31,32]

Per our transsphenoidal surgery postoperative protocol, patients are admitted to the neurosurgical intensive care unit for monitoring. Patients were retrospectively considered to have developed diabetes insipidus if they required treatment with desmopressin. Criteria for treatment with desmopressin in our postoperative protocol include urine output greater than 250 cc/h for two consecutive hours, urine specific gravity of <1.005, and either a rising serum sodium or a serum sodium ≥ 145 mmol/L. Postoperative steroid replacement was with hydrocortisone 10 mg/m^2 ($\sim$10–25 mg) daily in two divided doses. Steroids are continued for 2 weeks until a serum cortisol is checked.

The EHR was reviewed to determine utilization of inpatient endocrinology consultations and the pattern of postoperative follow-up with the respective surgeons and endocrinologist (institutional, private/community, or none). Outpatient follow-up was defined has having seen the surgeon or endocrinologist within 30-days of discharge.

Data Analysis

The primary outcome of interest was unplanned 30-day hospital readmission. All statistical analysis was completed on Stata 14.0 software (StataCorp, College Station, Texas, United States). Two-tailed t-test was used to compare continuous variables between groups. The Pearson Chi-square and Fisher exact test were used to compare categorical variables between groups. Univariable and multivariable logistic regression was performed to identify predictors of readmission. All statistics were two-tailed and considered statistically significant if $p < 0.05$.

Institutional Review Board Approval

This study was approved by the University of Miami Miller School of Medicine Institutional Review Board (IRB 20181136)

Results

Patient Demographics and Readmission Rates

A total of 409 patients were included in the study. The majority of the cohort was female (53.5%) and of white race (64.2%). Mean age of the cohort was 53.9 ± 16.5 years. Moreover, 69.8% of pituitary adenomas were nonfunctioning. However, 11.2% secreted adrenocorticotropin hormone, 8.4% secreted growth hormone, and 7.9% secreted prolactin (►**Table 1**).

A total of 57 patients (13.9%) were readmitted within 30 days of discharge. Medical reasons of readmission were more prevalent than surgical causes of readmission (57.9 vs. 43.9%). Hyponatremia was the most common cause of readmission (4.2%) followed by pain/headache (3.9%), CSF leak (3.4%), epistaxis (2.7%), hypernatremia (1.2%), and adrenal insufficiency (1.2%, ►**Table 2**).

Patients of White race (77.2 vs. 62.1%, $p = 0.028$) and sellar repair requiring nasoseptal flap (21.1 vs. 10.8%, $p = 0.028$) were more frequently readmitted. Readmitted patients also were more likely to have intraoperative high-flow CSF leak although this did not reach significance (26.3 vs. 14.2%, $p = 0.062$). There were no significant differences between the readmitted and nonreadmitted cohorts overall with respect to age, sex, BMI, tumor pathology, tumor size, length of stay (LOS), ESE, or postoperative diabetes insipidus (►**Table 1**).

Time to Readmission

Overall, the mean LOS for readmitted patients trended toward longer stays than patients not readmitted although it did not reach statistical significance (3.1 ± 2.0 vs. 2.7 ± 2.1 days, $p = 0.23$, ►**Table 1**). Mean time to readmission was 6.7 ± 6.0 days from discharge and 9.7 ± 6.6 days from surgery. However, time to readmission varied depending on the cause of readmission.

In general, patients with surgical causes of readmission trended toward earlier readmission than those with medical causes although this was not statistically significant (5.6 ± 4.1 vs. 7.4 ± 7.2 days from discharge respectively, $p = 0.117$). However, patients with hyponatremia were readmitted significantly earlier than other causes (4.3 ± 2.2 days from discharge, $p = 0.032$) with 88.2% readmitted within 7 days of discharge. This correlated to readmissions peaking on POD 7 (interquartile range: 5.5–8).

CSF leaks and epistaxis were also readmitted early. In total, 71.4% of CSF leaks and 81.8% of epistaxis patients were readmitted within 7 days of discharge (6.2 ± 5.2 and 4.9 ± 2.2 days from discharge, respectively). Patients with hypernatremia presented significantly later than all other complications (15.5 ± 19 days from discharge, $p = 0.032$). This correlated to POD 18 (►**Table 3**).

Hyponatremia

Hyponatremia was the most common cause of cause of readmission overall (►**Table 2**). Seventeen patients (4.2%) had delayed hyponatremia requiring readmission within 30 days of discharge, accounting for 29.8% of all readmissions. Serum sodium on readmission was 125 ± 6.0 mmol/L for those readmitted with hyponatremia versus 140 ± 4.6 mmol/L for those readmitted without hyponatremia ($t = 9.2$; $p < 0.001$).

When comparing patients readmitted with delayed hyponatremia to the remaining cohort, certain trends were appreciated (►**Table 4**). Patients of white race were readmitted more frequently (82.4 vs. 63.4%, $p < 0.001$). While not significant, patients with hyponatremia were more likely to be female (70.6 vs. 52.8%, $p = 0.150$) and have smaller (20.5 ± 11.4 vs. 22.6 ± 12.1 mm, $p = 0.52$) nonfunctioning tumors (75 vs. 69.6%, $p = 0.64$). Additionally, they trended toward lower incidence of ESE (58.9 vs. 74.5%, $p = 0.22$) and postoperative diabetes insipidus (35.4 vs. 45.5%, $p = 0.41$).

Coordination of Care

Endocrinology inpatient consultations were frequently utilized during the index admission. Overall, 91.1% of readmitted patients and 82.1% of the nonreadmitted patients were co-managed by endocrinologist as an inpatient (►**Table 1**). However, outpatient follow-up with an endocrinologist was less frequent. Readmitted patients had significantly less

Table 1 Demographics and population characteristics

Demographic factor		Total patients ($n = 409$)	Not readmitted ($n = 352$)	Readmitted ($n = 57$)	p-Value[a]
Admission age, y (mean ± SD)		53.9 ± 16.5	53.9 ± 16.8	53.8 ± 14.6	0.98
Sex (female)		219 (53.5%)	186 (52.8%)	33 (57.9%)	0.48
Race	White	262 (64.2%)	218 (62.1%)	44 (77.2%)	0.028
	African American	82 (20.1%)	75 (21.4%)	7 (12.3%)	
	Other	64 (15.7%)	58 (16.4%)	6 (10.5%)	
BMI (mean ± SD)		29.8 ± 6.7	29.8 ± 6.9	30.3 ± 5.1	0.57
Pathology	Nonfunctioning	275 (69.8%)	240 (70.6%)	35 (64.8%)	0.34
	ACTH	44 (11.2%)	34 (10.0%)	10 (18.5%)	
	GH	33 (8.4%)	27 (7.9%)	6 (11.1%)	
	Prolactinoma	31 (7.9%)	29 (8.5%)	2 (3.7%)	
Tumor size, mm (mean ± SD)		22.5 ± 12.2	22.1 ± 11.8	24.7 ± 13.7	0.13
Length of stay, d (mean ± SD)		2.8 ± 2.1	2.7 ± 2.1	3.1 ± 2.0	0.23
Days to readmission (mean ± SD)		N/A	N/A	6.7 ± 6.1	
POD to readmission (mean ± SD)		N/A	N/A	9.7 ± 6.6	
Extrasellar extension		302 (73.8%)	261 (75.9%)	41 (73.2%)	0.67
Intraoperative CSF leak					
	No leak	191 (46.7%)	169 (48.0%)	22 (38.6%)	0.062
	Low-flow leak	153 (37.4%)	133 (37.8%)	20 (35.1%)	
	High-flow leak	65 (15.9%)	50 (14.2%)	15 (26.3%)	
Seller repair					
	Any repair	346 (84.6%)	296 (84.1%)	50 (87.7%)	0.48
	Alloderm	324 (79.2%)	275 (78.1%)	49 (86.0%)	0.18
	Amnion	83 (20.3%)	72 (20.5%)	11 (19.3%)	0.84
	Nasoseptal flap	50 (12.2%)	38 (10.8%)	12 (21.1%)	0.028
Postoperative CSF leak		8 (2.0%)	5 (1.4%)	3 (5.3%)	0.14
Postoperative lumbar drain		14 (3.4%)	10 (2.8%)	4 (7.0%)	0.11
Postoperative diabetes insipidus		183 (45.1%)	159 (45.6%)	24 (42.1%)	0.63
Inpatient endocrine consult		340 (83.3%)	289 (82.1%)	51 (91.1%)	0.094
Outpatient endocrine follow-up		280 (68.5%)	248 (70.5%)	32 (56.1%)	0.031
Type of outpatient endocrinologist					
	Private	134 (32.8%)	122 (34.7)	12 (21.1%)	0.051
	Institution	146 (35.7%)	126 (35.8%)	20 (35.1%)	
	None	129 (31.5)	104 (29.5%)	25 (43.9%)	

Abbreviations: ACTH, adrenocorticotropic hormone; BMI, body mass index; CSF, cerebrospinal fluid; GH, growth hormone; N/A, not applicable; POD, post-operative day; SD, standard deviation.
[a]Reflects two-tailed *t*-test for continuous or Pearson's Chi-square/Fischer's exact test to compare categorical data between groups.
Note: Values are presented as number (%) unless otherwise indicated.

frequent follow-up with either an institutional or private endocrinologist than the nonreadmitted cohort (56.1 vs. 70.5%, $p = 0.031$; ►**Supplementary Table S1** (available in the online version).

When looking at patients readmitted with hyponatremia only, none of the variables in this study were predictive of 30-day readmission from delayed hyponatremia on either univariable or multivariable analysis. However, when analyzing risk factors for all cause readmission, multivariable analysis found patients of white race to be at increased odds of readmission compared with non-White patients (odds ratio [OR]: 2.24; 95% confidence interval [CI]: 1.09–4.58). Patients who had outpatient follow-up with any endocrinologist (private or institutional) were at lower risk of readmission compared with those without follow-up (OR: 0.46; 95% CI: 0.24–0.88). Coordination of postoperative follow-up with a

Table 2 Causes of readmission

Reason for readmission	Number of patients	Percent of total cohort ($n = 409$)	Percent of readmissions ($n = 57$)
Medical causes	33	8.1%	57.9%
Surgical causes	25	6.1%	43.9%
Cerebrospinal fluid leak	14	3.4%	24.6%
Epistaxis	11	2.7%	19.3%
Hyponatremia	17	4.2%	29.8%
Hypernatremia	5	1.2%	8.8%
Pain/headache	16	3.9%	28.1%
Adrenal insufficiency	5	1.2%	8.8%

private endocrinologist did not confer increased risk of readmission compared with follow-up with an institutional endocrinologist (►**Table 5**).

Mean postdischarge days to first postoperative follow-up with a surgeon and endocrinologist was 11.4 ± 11.1 and 23.3 ± 11.5 for the readmitted cohort and 8.3 ± 7.2 and 22.7 ± 13.8 for the nonreadmitted cohort, respectively. For those readmitted, 29 patients (50.9%) were readmitted prior to follow-up with a surgeon and 45 patients (79.0%) were readmitted prior to follow-up an endocrinologist. Furthermore, 57.1% of patients with CSF leak and 45.5% of patients with epistaxis were readmitted prior to follow-up with their surgeon. In addition, 64.7% with hyponatremia were readmitted prior to follow-up with their surgeon and 88.2% were readmitted prior to follow-up with an endocrinologist (►**Table 6**).

Discussion

In this study, the overall readmission rate following ETPS was 13.9%, which is similar to readmission rates reported in prior studies.[9,14–20] Endocrine dysfunction was more common in readmitted patients than surgical complications. The most common cause of readmission was hyponatremia which occurred in 4.2% of patients, accounting for 29.8% of all readmissions. Delayed hyponatremia has been well documented as one of the most common causes of readmission following ETSP. Hyponatremia occurs in up to 25% of patients with more severe or symptomatic requiring readmission between 2.7 and 7.6% of patients. Hyponatremia most frequently presented on POD 7, while hypernatremia presented most frequently on POD 18. These findings are consistent with the triphasic pituitary response first described by Olsen et al. The triphasic response is characterized by early hypothalamic dysfunction (postoperative diabetes insipidus), followed by vasopressin release from degenerating pituitary neurons (delayed hyponatremia), and finally depletion of vasopressin stores (delayed hypernatremia).[24]

Prior studies have failed to identify reliable predictors for delayed hyponatremia.[22,27,29,33–35] Studies have linked female sex, tumor size, preoperative hypopituitarism, and postoperative diabetes insipidus to delayed hyponatremia although currently no clear agreement exists on which patients are at greatest risk. Although this study found females comprised 70.6% of patients readmitted with hyponatremia, logistic regression analysis failed to identify any significant risk factors specific to delayed hyponatremia. This may have been related to a small sample size. This further highlights the ongoing challenge to identify high-risk patients.

In this study, we found that 87.5% of patients readmitted with hyponatremia were seen by inpatient endocrinology during the index admission, but only 58.8% had documented outpatient follow-up with either an institutional or community/private endocrinologist. Furthermore, 64.7% were readmitted prior to follow-up with a surgeon and 88.2% were readmitted prior to seeing an endocrinologist likely due to the relatively earlier onset of delayed hyponatremia. Our study also found low rates of outpatient follow-up with endocrinologist across the entire cohort with even lower rates in the readmitted cohort. Our analysis demonstrated follow-up with either an institutional or community/private endocrinologist within 30 days of discharge as the only variable to reduce risk of readmission

Table 3 Time to readmission

Reason for readmission	Days from discharge		Postoperative day		*p*-Value[a]
	Mean ± SD, d	Median (IQR), d	Mean ± SD, d	Median (IQR), d	
All causes	6.7 ± 6.1	5 (3–7)	9.7 ± 6.6	8 (6–10)	N/A
Medical causes	7.4 ± 7.2	4.5 (2–9)	10.5 ± 7.5	7.5 (5.5–14)	0.339
Surgical causes	5.6 ± 4.1	5 (3–6)	8.5 ± 5.3	8 (6–9)	0.117
Cerebrospinal fluid leak	6.2 ± 5.2	5 (2.5–6)	9.2 ± 7.0	7.5 (5–9)	0.388
Epistaxis	4.9 ± 2.2	5 (3–7)	7.8 ± 1.8	8 (7–9)	0.161
Hyponatremia	4.3 ± 2.2	4 (2.5–6)	7 ± 2.1	7 (5.5–8)	0.032
Hypernatremia	15.5 ± 19	15.5 (2–29)	18.0 ± 18.4	18 (5–31)	0.032
Pain/headache	9.2 ± 7.7	8 (2–15)	11.8 ± 8.1	10 (5–17)	0.075
Adrenal insufficiency	4.2 ± 2.6	3 (2–7)	9.4 ± 5.5	7 (6–9)	0.177

Abbreviations: IQR, interquartile range; N/A, not applicable; SD, standard deviation.
[a]Reflect two-tailed *t*-test for continuous variables between groups.

Table 4 Characteristics of patients readmitted with and without hyponatremia

		Hyponatremia		
Factor		**Without**	**With**	***p*-Value[a]**
n (*n* %)		392 (95.8%)	17 (4.2%)	
Admission age, y (mean ± SD)		53.9 ± 16.5	52.4 ± 15.8	0.70
Sex (female)		207 (52.8%)	12 (70.6%)	0.15
Race	White	248 (63.4%)	14 (82.4%)	<0.001
	African American	81 (20.7%)	1 (5.9%)	
	Other	63 (16.0%)	2 (11.8%)	
BMI (mean ± SD)		29.9 ± 6.8	29.4 ± 5	0.81
Pathology	Nonfunctioning	263 (69.6%)	12 (75%)	0.98
	ACTH	42 (11.1%)	2 (12.5%)	
	GH	32 (8.5%)	1 (6.2%)	
	Prolactinoma	30 (7.9%)	1 (6.2%)	
Tumor size, mm (mean ± SD)		22.6 ± 12.1	20.5 ± 11.4	0.52
Length of stay, d (mean ± SD)		2.8 ± 2.1	2.6 ± 1.1	0.81
Days to readmission (mean ± SD)		10.6 ± 10.9	4.3 ± 2.2	0.032
POD to readmission (mean ± SD)		13.7 ± 11.5	7.0 ± 2.1	0.028
Extrasellar extension		292 (74.5%)	10 (58.9%)	0.22
Intraoperative CSF leak				
	No leak	182 (46.4%)	9 (52.9%)	0.78
	Low-flow leak	148 (37.8%)	5 (29.4%)	
	High-flow leak	62 (15.8%)	3 (17.6%)	
Seller repair				
	Any repair	333 (84.9%)	13 (76.5%)	0.34
	Alloderm	311 (79.3%)	13 (76.5%)	0.78
	Amnion	81 (20.7%)	2 (11.8%)	0.37
	Nasoseptal flap	49 (12.5%)	1 (5.9%)	0.41
Postoperative CSF leak		7 (1.8%)	1 (5.9%)	0.48
Postoperative lumbar drain		13 (3.3%)	1 (5.9%)	0.57
Postoperative diabetes Insipidus		177 (45.5%)	6 (35.3%)	0.41
Inpatient endocrine consult		326 (83.2%)	14 (87.5%)	0.65
Outpatient endocrine follow-up		270 (68.9%)	10 (58.8%)	0.38
Type of outpatientendocrinologist				
	Private	130 (33.2%	4 (23.5%)	0.61
	Institution	140 (35.7%)	6 (35.3%)	
	None	122 (31.1%)	7 (41.2%)	

Abbreviations: ACTH, adrenocorticotropic hormone; BMI, body mass index; CSF, cerebrospinal fluid; GH, growth hormone; POD, postoperative day; SD, standard deviation.
[a]Reflects two-tailed *t*-test for continuous or Pearson's Chi-square/Fischer's exact test to compare categorical data between groups.
Note: Values are presented as number (%) unless otherwise indicated.

from all causes. Furthermore, follow-up with a community/private endocrinologist did not increase risk of readmission compared with institutional endocrinologist. These findings suggest interventions incorporating endocrinologist in the early postoperative care of patients may improve patient outcome and reduce readmission rates following ETPS.

While the readmitted cohort had a higher frequency of inpatient endocrine co-management versus the nonreadmitted cohort (91.1 vs. 82.1%), this was not found to be significant. The differences in inpatient endocrine co-management patterns may reflect surgeon preference. Some providers routinely incorporate endocrine in postoperative inpatient care while

Table 5 Univariable and multivariable odds ratio of all-cause 30-day readmission following endoscopic transsphenoidal pituitary surgery

Characteristic	Univariable analysis			Multivariable analysis		
	OR	95% CI	*p*-Value	OR	95% CI	*p*-Value
White race	2.01	1.08–4.01	0.028	2.24	1.09–4.58	0.028
BMI > 30	1.68	0.96–2.96	0.070	1.56	0.82–2.95	0.174
ACTH	2.02	0.92–4.44	0.081	2.24	0.98–5.14	0.057
Nasoseptal flap	2.21	1.07–4.53	0.032	1.67	0.75–3.74	0.211
Intraoperative high-flow CSF leak	2.30	1.11–4.77	0.025	1.60	0.75–3.42	0.224
Diabetes mellitus	1.92	0.99–3.96	0.052	1.44	0.73–2.83	0.291
Outpatient endocrine follow-up	0.54	0.30–0.95	0.033	0.46	0.24–0.88	0.019

Abbreviations: ACTH, adrenocorticotropic hormone; BMI, body mass index; CI, confidence interval; CSF cerebrospinal fluid; OR, odds ratio.

Table 6 Days to first postoperative follow-up

		Postdischarge days to follow-up				Readmitted prior to follow-up	
Reason for readmission	*n*	Surgeon[a]		Endocrinologist[b]		Surgeon[a]	Endocrinologist[b]
		Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)	*n* (*n* %)	*n* (*n* %)
Not readmitted	352	8.3 ± 7.2	6 (5– 8)	22.7 ± 13.8	21 (13–30)	N/A	N/A
Readmitted	57	11.4 ± 11.1	8 (4– 16)	23.3 ± 11.5	20.5 (16.5– 27.5)	29 (50.9%)	45 (79.0%)
Cerebrospinal fluid leak	14	15.1 ± 15.6	11 (5– 21)	28.2 ± 8.3	27 (26–29)	8 (57.1%)	10 (71.4%)
Epistaxis	11	7.9 ± 5.8	6.5 (4– 8)	13 ± 9.9	13 (6– 20)	5 (45.5%)	11 (100%)
Hyponatremia	17	12.8 ± 10.5	10 (5– 21)	22.6 ± 10.7	23 (15–27)	11 (64.7%)	15 (88.2%)
Hypernatremia	5	8.3 ± 3.5	8 (5– 12)	38 ± 22.6	38 (22–54)	2 (40%)	5 (100%)
Adrenal insufficiency	5	13.3 ± 9.4	13.5 (6– 20.5)	25.5 ± 3.5	25.5 (23–28)	4 (80%)	5 (100%)
Pain/headache	16	14.2 ± 16.7	8 (5–21)	18.1 ± 6.8	17 (15–26)	9 (56.3%)	14 (87.5%)

Abbreviations: IQR, interquartile range; N/A, not applicable; SD, standard deviation.
[a]Follow-up with either a neurosurgeon or otolaryngologist.
[b]Follow-up with either institutional or community/private endocrinology.
Note: Values are presented as number (%) unless otherwise indicated.

others prefer to manage patients unless it becomes more complicated. While these trends are interesting, we did not find any statistically significant associations except for frequency of outpatient endocrine follow-up. This may suggest that readmissions related to endocrine dysfunction are likely to occur in the outpatient rather than the immediate postoperative period. This can be highlighted by the fact that inpatient endocrinologist help manage postoperative diabetes insipidus and adrenal insufficiency; yet there was no association between diabetes insipidus and readmission.

Several centers have implemented various strategies to reduce readmissions from delayed hyponatremia. Checking a serum sodium 5 to 8 days postoperatively to identify patients with delayed hyponatremia would be a relatively simple screening method. This timing corresponds to the nadir in serum sodium on POD 7 and previously described by the triphasic response of the pituitary gland following ETPS. Treatment of hyponatremia is then tailored to the severity of hyponatremia. Mild hyponatremia (i.e., 130–135 mmol/L) can be managed with fluid restriction as an outpatient, whereas severe or symptomatic hyponatremia (<125 mmol/L) often requires hospitalization for aggressive fluid restriction, hypertonic saline, or administration of vaptans.[36] Other studies have demonstrated the utility of postoperative fluid restriction to reduce readmissions from delayed hyponatremia. Deaver et al utilized a 1.5-L daily fluid restriction postoperatively as well as routine follow-up with a neurosurgeon and endocrinologist. Serum sodium levels 7 days after discharge was then used to dictate management of sodium imbalances.[30] This intervention was able to readmissions from delayed hyponatremia by 70%. In similar study, investigators implemented 1,000 mL of fluid restriction from POD 4 to 8. Patients were discharged on POD 1 and a dedicated endocrinologist monitored patients via telephone from POD 2 to 4. The investigators had no cases of either asymptomatic or severe hyponatremia.[37] In a similar study by Burke et al, patients were discharged with a 1-L fluid restriction

and had no readmissions related to hyponatremia.[38] Future interventions should consider endocrinologist in medication reconciliation to educate patients on appropriate Desmopressin use to avoid iatrogenic hyponatremia prior to discharge. Lastly, the incorporation of postoperative Telehealth visits may be an adjunctive intervention to follow-up with patients at prevent hospital readmissions.[39]

Our findings in conjunction with the aforementioned studies underscore the importance of incorporating endocrinologist in the postoperative care of patients following ETPS. Multidisciplinary teams incorporating endocrinologist and postdischarge protocols checking serum sodium can help identify patients at risk of readmission from delayed hyponatremia. Early interventions such as prophylactic fluid restriction may help in reducing 30-day readmissions from delayed hyponatremia.

Several variables and trends were reported in this study that did not reach statistical significance including intraoperative high-flow CSF leak, LOS, radiographic size of tumors, functioning tumors, ESE, and postoperative diabetes insipidus. We include these trends to highlight variables that may be significant with appropriate power in future studies.

Limitations

This study has several limitations. First, the overall rate of readmissions following ETPS is low, particularly when analysis is stratified on specific causes of readmission. Thus, lack of power may have limited identification of significant variables. In particular, the association of functioning adenomas and its risk in developing postoperative electrolyte imbalances and CSF leaks was analyzed in subset analysis. No statistical association was identified, which may be related to lack of power. Future studies should consider these in their analysis. Second, patients may have been readmitted to an outside facility, causing us to underestimate readmission rates. This would however not be very significant as patients are seen routinely postoperatively at our institution at 6 weeks after surgery, capturing information on readmission at another facility. Lastly, recent changes in practice patterns may have also contributed to lower readmission rates. Our center recently began utilizing postdischarge serum sodium levels to identify and treat delayed hyponatremia.

Implications for Practice

In an effort to reduce 30-day readmission, there is a growing need to balance quality of care and efficiency. Patients undergoing ETPS are unique in that postoperative complications include both surgical complications and metabolic derangements related to the pituitary gland. With decreasing length of hospital stays over the last decade, identification of causes and risk factors for readmission as well as time to presentation can help guide targeted quality improvement measures. A multidisciplinary approach incorporating endocrinologist and protocols assessing for electrolyte imbalances may help identify patients at risk of hyponatremia and guide treatment. Additionally, the coordination of care with a private endocrinologist is a safe alternative for patients travelling from afar.

Conclusion

This study looked at 30-day readmission following ETPS at a high-volume tertiary care center. Overall, 13.9% of patients were readmitted within 30 days of discharge. Metabolic derangements were more frequent than surgical complications. Postoperative hyponatremia was the most common cause (4.2%) and most likely to present on POD 7. Outpatient follow-up with an endocrinologist was found to reduce risk of readmission from all causes. A multidisciplinary approach incorporating endocrinologist in the postdischarge period may help reduce 30-day readmissions. Data from this study can be used by hospital, administrators, quality improvement officers, and providers to identify high-risk patients and develop targeted interventions to reduce 30-day readmissions.

Note
Interim results of this study were presented as a poster at the 2019 American Rhinologic Society Meeting in September 2019, New Orleans, LA.

Authors' Contributions
M.K.G. supported in study design, data collection, analysis, and presentation. D.E.C. and C.L.D. performed data collection, analysis, and presentation. A.P.K., D.G.E., H.Z., A.R.A., A.Y.K., and R.J.K. carried out study analysis. Z.S. contributed to study design, analysis, and presentation.

Funding
None.

Conflict of Interest
None declared.

Acknowledgments
The authors are indebted to Alejandro Mantero, PhD, MA, for statistical suggestions and analysis of the data obtained from this cohort.

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