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Patient and caregiver perspectives of fluid discharge protocols following pituitary surgery

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ABSTRACT

Background: Post-operative fluid restriction after transsphenoidal surgery (TSS) for pituitary tumors may effectively prevent delayed hyponatremia, the most common cause of readmission. However, implementation of individualized fluid restriction interventions after discharge is often complex and poses challenges for provider and patient. The purpose of this study was to understand the factors necessary for successful implementation of fluid restriction and discharge care protocols following TSS.

Methods: Semi-structured interviews with fifteen patients and four caregivers on fluid discharge protocols were conducted following TSS. Patients and caregivers who had surgery before and after the implementation of updated discharge protocols were interviewed. Data were analyzed inductively using a procedure informed by rapid and thematic analysis.

Results: Most patients and caregivers perceived fluid restriction protocols as acceptable and feasible when indicated. Facilitators to the protocols included clear communication about the purpose of and strategies for fluid restriction, access to the care team, and involvement of patients' caregivers in care discussions. Barriers included patient confusion about differences in the care plan between teams, physical discomfort of fluid restriction, increased burden of tracking fluids during recovery, and lack of clarity surrounding desmopressin prescriptions.[1]

Conclusion: Outpatient fluid restriction protocols are a feasible intervention following pituitary surgery but requires frequent patient communication and education. This evaluation highlights the importance of patient engagement and feedback to effectively develop and implement complex clinical interventions.

Background

Delayed hyponatremia has been reported in up to one-third of patients following transsphenoidal surgery (TSS) for pituitary and sellar lesions and is the most common cause of hospital readmission [1–5]. The decline in serum sodium levels is attributed to syndrome of inappropriate diuretic hormone secretion (SIADH) following surgical manipulation of the pituitary. Excess release of arginine vasopressin (AVP) leads to a drop in urine output by post-operative day (POD) 4 with serum sodium nadir usually occurring by POD 7 or 8 [2]. Less frequently, hyponatremia is preceded and/or followed by periods of polyuria from AVP deficiency (AVP-D, previously known as central diabetes insipidus) as part of a biphasic or triphasic response [1,2,6]. However, with fast-track discharge within a few days after pituitary TSS becoming more common [7], most patients have been discharged from the hospital when hyponatremia is expected to occur. Symptomatic and severe

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[1] **Abbreviations**: **TSS** – transsphenoidal surgery; **POD** – post-operative day; **AVP-D** – arginine vasopressin deficiency; **SIADH** – syndrome of inappropriate antidiuretic hormone secretion

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hyponatremia (sodium <125 mEq/L) often necessitates readmission and ICU care with an associated mean readmission cost of over $12,000 [5].

Efforts to reduce hyponatremia and related readmissions include post-operative outpatient sodium monitoring and follow-up phone calls to assess symptoms [8]. These interventions alone are typically insufficient to prevent readmission [8–10]. Recently, prophylactic fluid restriction after discharge has been shown to significantly reduce hyponatremia and readmission rates [11–13]. However, not all patients may be appropriate for fluid restriction, especially when there is concern for ongoing polyuria past discharge. Thus, the implementation of fluid restriction protocols after TSS remains complicated and labor-intensive, requiring significant coordination between the patient, neurosurgery and endocrinology providers, caregivers, and other members of the clinical team.

Knowledge of patient and caregiver perspectives and comprehension of post-discharge fluid protocols is currently lacking. To address this gap in knowledge, our institution launched a multi-faceted group of interventions to streamline the patient protocols surrounding fluid intake with the overall goal of preventing hyponatremia-related readmissions after TSS. We then carried out a series of interviews using the lens of implementation science to explore the patient and caregiver experience of post-operative pituitary surgery care before and after these interventions.

Methods

Study design

Qualitative, semi-structured interviews of patients and their caregivers were conducted following endoscopic pituitary TSS. The study was completed at (institution name removed), a tertiary academic medical center that performs over 100 pituitary TSS annually. New hospital and discharge interventions and updated fluid restriction protocols were deployed in January 2022 as part of a quality improvement initiative to reduce post-operative hyponatremia and readmission rates (Fig. 1). Prior to January 2022, patients received only verbal counseling about 1L fluid restriction if they did not have AVP-D and were instructed to have a POD 8 sodium check. Desmopressin 0.1 mg oral tablet was prescribed on discharge to take on an as-needed basis for patients who had at least one episode of sustained polyuria that met criteria for inpatient post-operative desmopressin use and AVP-D in the hospital. The updated criteria in January 2022 for inpatient desmopressin use was 1) urine output >400 mL/hour for ≥3 consecutive hours, 2) urine specific gravity ≤1.004, and 3) plasma sodium ≥142 mEq/L). All three criteria had to be met for desmopressin to be given. Before the new protocol, desmopressin was allowed to be given when urine output was >250 mL/hour for 2+ hours and urine specific gravity ≤1.004 without a sodium requirement. After discharge, patients are instructed to discuss with the endocrine team about signs of high urine output (>400 mL/hour) and unquenchable thirst prior to taking any desmopressin at home. Interview questions were focused to elicit participants' perspectives of patient priorities; patient education before and after surgery; understanding of fluid monitoring, feasibility, and acceptability of fluid restriction after discharge; use of desmopressin for patients with ongoing signs of AVP-D; and caregiver support. The full interview protocol is available in **Supplementary Material**.

As this project was part of a quality improvement effort, it did not meet the definition of human subjects research as determined by (institution's) Institutional Review Board. All individual interview participants gave verbal consent prior to interviews.

Study participants

Adult patients (age ≥18 years) who underwent pituitary TSS between September 2021 and April 2022 at our institution and their caregivers were targeted for interviews. Patients with pre-existing AVP-D before surgery were excluded, as such patients were uniformly told not to fluid restrict and to resume desmopressin medication at their home dose. Patients with a hospital length of stay of more than 5 days were also excluded, as they would not have time to follow outpatient discharge protocols and were also more likely to have acute complications that may contribute to hyponatremia (e.g., infection, surgical site hematoma, cerebrospinal fluid leak). Eligible caregivers were those connected to patients based on the above criteria.

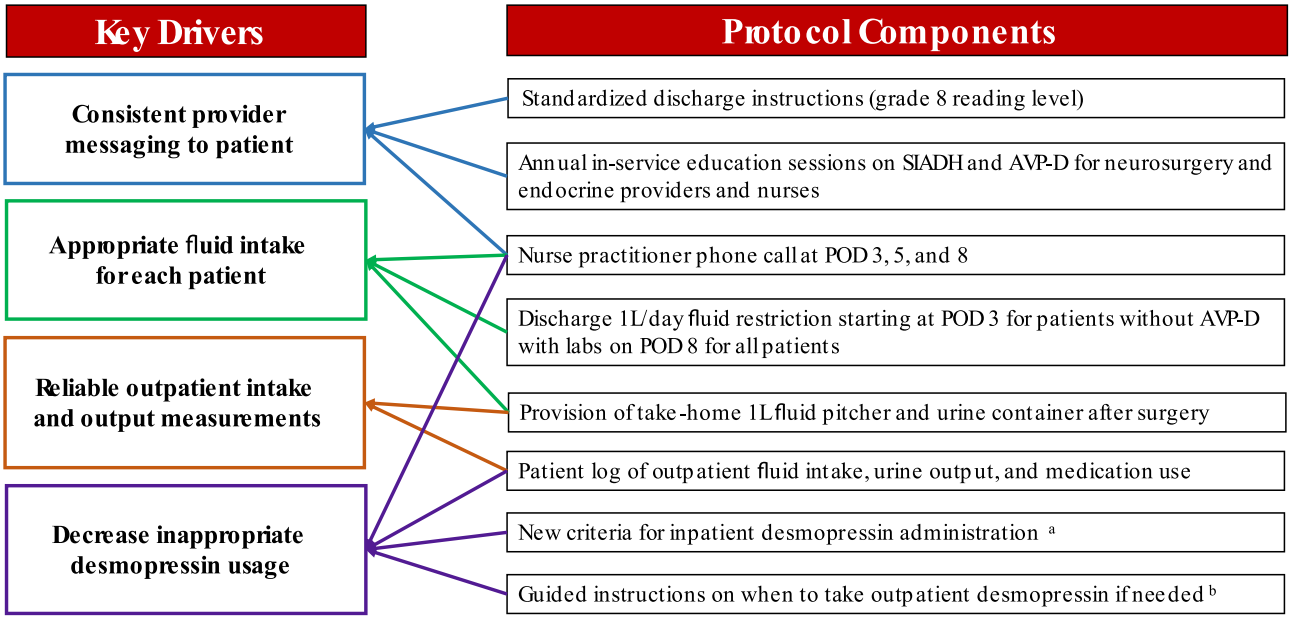

Fig. 1. Key drivers and discharge protocol components after pituitary surgery to reduce readmissions from hyponatremia. Patients received the full package of updated discharge protocol components after January 2022. [a] Desmopressin given in the hospital if urine output > 400 mL per hour for 3 h, urine specific gravity ≤ 1.004, and 3) plasma sodium ≥ 142 mEq/L. [b] Patients may be instructed to take desmopressin at home if urine output > 400 mL per hour for at least 3 h in a row and unquenchable thirst, on consultation with endocrine team. Abbreviations: SIADH = syndrome of inappropriate diuretic hormone secretion; AVP-D = arginine vasopressin deficiency; POD = post-operative day.

Interview data collection

Eligible participants were contacted by phone and invited to participate in a 30-minute semi-structured individual phone interview. Participants were contacted at least three weeks out from their initial hospital discharge date to avoid interfering with immediate post-operative care needs. All patient outreach and interviews were conducted by a single researcher (AA). Following each interview, patients were invited to share their caregiver's contact information to be contacted for an interview following the same procedures. Patient-caregiver pairs were denoted by matching numbers (i.e., "Patient 4" was cared by "Caregiver 4"). Outreach was directed to gather patient and caregiver perspectives both prior to ("*pre*") and following ("*post*") the deployment of new discharge interventions in January 2022. Outreach also was directed to both patients who were on fluid restriction protocols as well as those who were given as-needed desmopressin and told to drink to thirst. Interviews and outreach ceased upon reaching thematic saturation, the point at which additional data no longer led to the identification of new information [14].

Data analysis

Interview recordings were transcribed verbatim using a HIPAA-compliant service (TranscribeMe; Oakland, CA, USA). Transcribed interviews were analyzed inductively using a multiphase analysis approach leveraging rapid analytic procedures (e.g., template summaries) to extract early themes, coding of transcript summaries to produce interim results, and a matrix analysis of interview excerpts for final comparison of themes across all participants [15,16]. A subset of five transcripts were reviewed and discussed by all authors to establish consensus on coding approach before health services researcher (AA) completed remaining coding. All transcripts and coding were subsequently reviewed by physician researchers (JJC) and (SV) to support the identification of key themes [14].

Table 1
Demographics and Clinical Characteristics of Interviewed Patients and Caregivers.

Participant Characteristics		n	%
Demographics of Patients and Caregivers (n = 19)	Sex		
	Woman	11	58
	Man	8	42
	Race/Ethnicity		
	White	13	68
	Non-White	6	32
	Age (years)		
	20–39	8	42
	40–54	6	32
	55+	5	26
	Role		
	Patient	15	79
	Caregiver	4	21
	Exposure to new discharge protocols		
	No (Pre-January 2022)	9	47
	Yes (Post-January 2022)	10	53
Clinical Characteristics of Patients (n = 15)	Pathology		
	Lactotroph adenoma	6	40
	Somatotroph adenoma	5	27
	Somatolactotroph adenoma	3	20
	Rathke cleft cyst	1	7
	Gonadotroph adenoma	1	7
	Instructed to fluid restrict	8	53
	Prescribed outpatient desmopressin	9	60
	Instructed to take outpatient desmopressin	4	27
	Hyponatremia (Na ≤ 134 mEq/L)	3	20
	30-day readmission due to hyponatremia	1	7

Demographic information of patients and caregivers are presented together to protect potentially identifiable information.

Results

Out of 68 patients who met study criteria and underwent pituitary surgery during the study time frame, a total of 19 interviews were conducted, which included 15 patients (of 30 contacted) and 4 caregivers (of 5 contacted). Ten patients and one caregiver were unable to be successfully reached, and five patients declined to participate. Out of those who completed interviews, eight patients and two caregivers received the new set of discharge interventions. Demographics of interview participants and clinical characteristics of post-operative care are provided in Table 1.

Slightly over half of patients were given explicit instructions to restrict fluid intake (n=8/15, 53%) on discharge with the majority of these (6 out of 8) receiving the new discharge protocols. The remaining seven patients were told to drink to quench thirst due to concern for ongoing polyuria. Nine patients were prescribed desmopressin on an as needed basis for excessive urination, and four patients took the medication at home.

Mild hyponatremia was observed in two patients (sodium 133 mEq/L for both patients), and one patient was readmitted for symptomatic moderate hyponatremia (sodium 125 mEq/L) within 14 days of discharge. All three patients with hyponatremia were told to drink to quench thirst on discharge instead of fluid restriction. Two of these patients, including the patient who was readmitted, took desmopressin at home and received the former protocol of discharge care.

Interview themes

Overall, most patients reported that post-discharge fluid recommendations were feasible and acceptable to follow, though many patients found fluid restriction challenging from a physical and logistical perspective. Patients and caregivers who received the additional support from the new discharge protocols found the education and fluid monitoring materials to be beneficial. Several key facilitators (Table 2) and barriers (Table 3) to successful adherence to the fluid protocols emerged from interviews, alongside corresponding opportunities for improvement.

Facilitator: Education related to fluid optimization

Fluid-related educational content included anticipatory guidance regarding physiological fluid shifts and the need for fluid restriction or medication in most cases. Patients were generally satisfied with these conversations. These conversations took place within the context of other surgical recovery topics, which included restrictions on general movement and nasal care (i.e., avoiding blowing or picking at nose, avoiding use of a straw).

While some patients described learning about sodium and fluid management during pre-operative appointments prior to surgery, most patients reported not learning about it until after the surgery when they were recovering in the hospital. Post-operative education was often problematic as fatigue or sedation from pain medication presented comprehension challenges for many patients. A few participants desired additional details about post-operative recovery, particularly as it related to their unique case, desiring more personalization of written and verbal instructions.

Facilitator: Fluid monitoring tools

Patients whose surgeries took place after January 2022 received fluid monitoring tools, specifically a 1-liter drinking pitcher and a urine

Table 2
Facilitators to Fluid Discharge Protocols Following Pituitary Surgery and Amplification Strategies as Identified from Patient and Caregiver Interviews.

Facilitators	Example quotations from patients and caregivers	Amplification strategies
Education related to fluid optimization	"The neurosurgeon's nurse talked me through, 'Here's all the possibilities of things after surgery from the sodium and the fluid imbalance.' …They went through all the potential possibilities… It was just the reassurance of, 'Hey, they're going to tell me everything good, bad, and ugly so that I can be best prepared.' You're not walking into it blind." (Patient 8-pre)	Introduce content in the pre-operative setting. Personalize education. Deliver consistent messages in written & verbal formats.
Physical monitoring tools	*"One of the nurses was a really good teacher in explaining all the different tools that I had, like the water measuring cup for drinking and then the hat and everything that I had for measuring urine and all of that."* (Patient 4-*post*) "*Having that chart to be able to record all of that was super helpful. I mean, it was really annoying to have to do that [laughter] for a week… But yeah, they explained it…And then I just brought it back at my next follow-up appointment.*" (Patient 14-*post*)	Emphasize continued use by the clinical team and request data during post-operative encounters. Digitize fluid log and printed materials. Provide written instructions in multiple places.
Caregiver involvement	*"When I was super thirsty and I'd only have 1,000 ml [to drink], [she was] just kind of encouraging me, that moral support for spreading out my liquid intake."* (Patient 4-*post)*	Involve caregivers during pre-operative counseling and discharge education. Increase flexibility around visitors regarding COVID-19.
Post-discharge communication with team	*"They fully support my recovery even after I was discharged from the hospital. There's always contact from them. And whenever I have a question, I always can get a fast answer from them, whether it's through the call or through the MyHealth app."* (Patient 12-*pre*)	Streamline care coordination across multidisciplinary teams (neurosurgery, endocrinology, ear nose & throat surgery, etc.)

Table 3
Barriers to fluid discharge protocols following pituitary surgery and mitigation strategies as identified from patient and caregiver interviews.

Barriers	Example quotations from patients and caregivers	Mitigation strategies
Physical discomfort of fluid restriction	*"There was an endocrinologist. We kind of had a little battle about how much water I was drinking … because when you've got a tape kind of under your nose, and you can't breathe through your nose that well and breathe through your mouth, you get thirsty. [The instructions were] you drink when you're thirsty, not just to drink. And I said, 'But I'm thirsty.' So we kind of argued about that."* (Patient 7-*pre*)	Clarify what constitutes a qualifying fluid (i.e., all liquids at room temperature vs. no free water). Acknowledge discomfort of fluid restriction while emphasizing its temporary nature.
Competing patient priorities	*"There were a few nurses or staff members who I wanted to tell, 'This is huge to me. This is every day for you, but this is giant to me.' That this is my husband who a week ago was losing his sight. It was giant for us."* (Caregiver 2-*post*)	Support managing patient expectations, including linking sodium and fluid optimization to desired outcomes (i.e., avoidance of a readmission) Link to patient network to share experiences.
Vague instructions regarding medication & red flag signs & symptoms	*"There was some confusion, I think, initially as to at what point to take [desmopressin]. How much was my output? How much was my input before I should take it kind of thing. And so I know there was some initial confusion on my part. Eventually, we were able to come up with a set schedule. And that really helped kind of clear it up."* *(Patient 11-pre)* *"And they pretty much just said I should take [desmopressin] whenever I noticed myself urinating a lot. And so that was kind of confusing to me. It was just hard for me to tell and gauge that myself."* (Patient 3-*post*)	Offer concrete instructions as to when to take desmopressin. Connect with patients as they transition to a new care plan. Share a list of pituitary-specific red flag signs and symptoms for patients following discharge.

"hat" or container to capture urine output. Patients also received pre-printed logs with fields to record fluid intake, urine output, and medication use. These materials were viewed as universally helpful, and each element of the intervention appeared to reinforce the overall message regarding fluid restriction.

A few patients reported forgetting to use the logs, and others felt that monitoring added an extra burden to their already challenging recovery process and tracking other vital signs. One patient stopped using the fluid log after two days when he was not asked about it by the care team during a follow-up encounter, feeling that its importance was not emphasized. This was echoed by another patient who felt the fluid log instructions in the information packet needed to be clearer. Finally, an option for a digitized log was preferred to facilitate consistency and ease of use, especially for those who are visually impaired.

Facilitator: Caregiver involvement

All except two patients had caregiver support during their surgery preparation and recovery process. Those with caregiver support universally described this as extremely helpful. While a minority of patients preferred to monitor their fluids on their own, many caregivers helped patients log their intake and output, adhere to fluid restriction, or review fluid decisions.

In addition, caregivers were also involved in several other post-operative care activities, such as lifting, helping move the patient, reminding the patient to take medications, and processing information related to the care plan.

There was universal desire on the part of both patients and caregivers to have caregivers present during care conversations with the clinical team, particularly in pre-operative discussions where the recovery process was discussed or during instructional conversations just prior to

hospital discharge. However, this was often not possible due to COVID-19 visitor restrictions, caregiver availability, and/or caregiver disability. Caregivers sometimes missed information about fluid monitoring as a result. Other opportunities to better engage caregivers also emerged, including caregiver-specific written discharge instructions and a designated caregiver portal.

Facilitator: Post-Discharge communication with clinical team

Most patients felt that communication with the clinical team after surgery was strong, with prompt responses to patient and caregiver messages and phone calls. The content of these conversations focused on expectation setting, reviewing current symptoms, and answering questions.

While the clinical team was highly accessible, some communication challenges arose involving care coordination across the three involved clinical specialties (neurosurgery, endocrinology, otolaryngology). Points of discrepancies included fluid restriction and desmopressin instructions. Inconsistent messaging contributed to confusion for a patient with initial AVP-D who was then readmitted with delayed hyponatremia. The caregiver shared their experience with this challenge:

> "We would get a call from neurosurgery in the morning and then a call from endocrinology in the afternoon, and then they would have different opinions, and then they would have to talk to each other. That's probably my biggest take away from this entire experience… I felt like we were getting different information from different people depending on the functional area." (Caregiver 9-pre)

Fortunately, lack of care coordination was not a dominant theme across respondents. Most interviewees did not comment on confusion or delays caused by differences in specialty recommendations.

Barrier: Physical discomfort of fluid restriction

Several patients shared that despite the supportive measures described above, the physical act of restricting liquid intake was a major challenge, even described as "*miserable*" (Patient 2-*post*) by one. The experience of being unable to drink freely was also exacerbated by other physical limitations. Another patient reported compensating by eating fruit with high water content. Patients also reported some confusion regarding whether such fruits or fluids with added electrolytes should be included in patients' allotted fluid.

Barrier: Competing patient priorities

Patient priority areas were typically outside of fluid intake considerations. Instead, primary concerns focused around wanting to know the outcome of the surgery, such as whether the tumor was fully resected or the pathology of the tumor. Physical symptoms such as pain management was also a priority, as was a desire for rapid improvement. Connection with similar patients also undergoing surgery through a patient network was desired to share experiences.

Other post-operative complications (cerebrospinal fluid leak, constipation, insomnia) and non-medical issues (financing and childcare during recovery, care coordination with out-of-state providers) took main precedence for many. Thus, fluid balance and sodium concerns often fell lower on participants' priorities.

Barrier: Vague desmopressin medication & red flag monitoring instructions

Several participants reported confusion over the purpose of desmopressin and, to a lesser degree, the signs and symptoms that should trigger them to return to the emergency room. For those prescribed desmopressin, it was unclear as to when to take it.

> *"[I] would have appreciated a lot more specific guidance, 'If you go this many times in an hour, or you urinate this much within an hour, this volume, you might need to take this.'"* (Patient 10-*post*)

Similarly, one patient's caregiver second-guessed her own choice in giving her partner desmopressin on an as-needed basis. When she checked in with the clinical team who suggested a reduced dose, she was concerned about the overall subjectivity in dosing. As mentioned previously, disparate messages regarding the care plan between diverse clinical teams and roles regarding dosing appeared to exacerbate the challenge. A few patients reported no confusion regarding desmopressin, but they did not need to take it based on their symptoms.

A list of clearer pituitary-specific red flag signs and symptoms was also requested by patients and caregivers to help signal for when patients should seek a higher level of care. The patient who was re-hospitalized for hyponatremia attributed their readmission to a lack of understanding about these symptoms and what to look for.

Discussion

Our analysis examines the patient and caregiver experience with fluid restriction and discharge interventions following pituitary surgery. In general, fluid restriction of 1 L per day was felt to be feasible to accomplish by patients and caregivers, though certain elements of the protocols remained difficult to understand. As evidence on the benefit of fluid restriction to reduce hyponatremia-related readmissions continues to build, more institutions are likely to adopt similar discharge protocols. Our evaluation demonstrates that successful implementation of these interventions may depend on several patient- and caregiver-directed measures as well as team coordination (Table 4).

From our interviews, we discovered that the post-operative hospital period is a non-ideal setting to introduce the concepts of fluid monitoring and fluid restriction due to competing patient priorities and altered sensorium from pain medication and fatigue. Shifting some of this education to the pre-operative setting during outpatient neurosurgery and endocrinology visits can largely help patients anticipate and adhere to post-discharge fluid restriction, and counseling becomes reinforced over multiple timepoints. One caveat is that not all patients are instructed to fluid restrict. Indeed, nearly half of our interviewed patients were told to drink to thirst initially on discharge due to concern for ongoing AVP-D. Thus, there remains potential for conflicting recommendations about fluid restriction between the pre-operative visits and time of discharge. Reviewing expected fluctuations in sodium and fluid balance with the patient, addressing both possibilities of AVP-D and delayed hyponatremia, the reasoning behind fluid restriction protocols (potential benefit of reduced risk of readmission), and setting expectations that fluid recommendations may change after discharge can help cover all potential outcomes.

Daily phone or email contact with patients following fast-track discharges have been reported as a feasible model for post-TSS care, some in combination with fluid restriction protocols [7,9,12]. However, due to available staffing coverage or reimbursement structures, daily and weekend communication can often still be challenging and laborious to implement. We have found that information from the patient-recorded fluid and urine logs can augment patient and providers' confidence in whether starting or continuing fluid restriction is safe and appropriate. This perhaps lessens the need for daily or weekend communication as long as the patient is tracking normal urine output. In contrast, records of particularly high or frequent urine output at home may be a signal for when patients should call in and discuss whether fluid intake should be liberalized. Another potential future option may be through digitization of fluid and urine logs through remote bladder monitoring with home uroflowmetry devices [17], allowing providers to contact patients when urine output seems excessive.

Related to urine monitoring, a recurrent theme in our interviews was lack of clarity on when to take desmopressin for patients who were

Table 4
Suggested recommendations on implementation of fluid discharge protocols following pituitary surgery.

- Introduce concepts of post-operative fluid monitoring and reasoning behind fluid restriction (potentially reduced risk of readmission) during pre-operative endocrine or neurosurgery visits and reinforce upon hospital discharge.
- Identify caregivers early and include in pre-operative and post-operative fluid education.
- Instruct patients to record and share fluid intake and urine output after discharge to determine appropriateness of fluid restriction.
- Acknowledge that fluid restriction may feel uncomfortable initially but is a temporary measure (typically ~5 days) and does not lead to clinical dehydration when recommended appropriately.
- Inform patients to alert provider for signs of ongoing AVP-D (e.g., urine output >400 mL per hour every 1-2 hours).
- Plan for frequent communication (phone or online portal messages) every 2-3 days with patients after hospital discharge and every 1-2 days in those with AVP-D.
- Limit desmopressin use during SIADH phase. Involve endocrine provider early in decision of whether patient should take desmopressin.
- Obtain sodium on POD 7-8 with same-day communication of results to patient and further instruction on whether to liberalize or continue fluid restriction.
- Maintain close and unified communication between all teams involved in pituitary care.

Abbreviations: AVP-D = arginine vasopressin deficiency; SIADH = syndrome of inappropriate diuretic hormone secretion; POD = post-operative day.

prescribed it. Though many pituitary endocrinologists agree that post-operative desmopressin may be administered "on demand" after surgery [18], leaving this decision to patients after discharge often leads to confusion and can be risky as self-guided desmopressin use may exacerbate delayed hyponatremia during the SIADH phase. This was especially true for patients who had limited guidance on as-needed desmopressin prior to the new discharge protocols though overly specific instructions from our new interventions proved to be challenging to follow as well. As sodium levels can drop rapidly by the day, providers and patients must be cautious with desmopressin usage. Patient education efforts were focused on closely tracking urine output the week following surgery and providing simple but clear warning signs of when to immediately involve the clinical team as described above (e.g., "*contact team if urine output is more than 400 mL per hour for 3 h in a row*"). This approach seems to minimize unnecessary usage of desmopressin and allow further conversations to develop between provider and patient regarding fluid intake and sodium monitoring and whether desmopressin may be indicated.

A key patient concern about fluid restriction is sensation of dry mouth and feeling of dehydration, especially for those who are used to and enjoy drinking a lot of fluids prior to surgery. However, given the potential for decrease in hyponatremia and readmission rates, we do recommend and reinforce adherence to the fluid restriction if deemed clinically appropriate based on patient's urine output (i.e. not exhibiting signs of AVP-D). We acknowledge with patients upfront that fluid restriction may be initially uncomfortable, but it is feasible and has been performed successfully by the vast majority of patients at our institution for whom it is recommended. We also emphasize that fluid restriction is a temporary measure, and patients will be allowed to drink normally if their POD 8 lab test shows a normal sodium. This latter point may improve patient motivation to complete POD 8 labs in a timely manner, and the discussion overall seems to generally lessen patient's concerns and fears.

The role of caregiver support was often highlighted by patients as a uniformly positive factor in the post-discharge recovery process following TSS. Caregivers often took on a lead role in reviewing discharge instructions, providing medications, reinforcing fluid monitoring for patients, and serving as patient advocates to the clinical team. Visitor restrictions during the COVID-19 pandemic often led to a negative emotional toll on patients as well gaps in caregiver knowledge that may have affected patient's recovery. Even as COVID-19 restrictions ease, it is beneficial for caregivers to be identified prior to surgery and be included during pre-operative and post-operative visits and the discharge counseling process either by phone, video, or in-person, whenever possible. This can help caregivers anticipate and manage the post-surgical recovery course, thereby reducing caregiver stress [19].

Lastly, interdisciplinary communication within provider teams across discharge is a unique challenge with post-operative TSS care, and this was described by a few interviewees as barriers during discharge or factors to readmission. Discharge counseling at teaching hospitals is often performed by several providers at different levels of training, and each specialty may also focus on separate aspects of the patient's discharge care. Due to the complexity of post-TSS care, some institutions have a dedicated pituitary endocrine service with inpatient and outpatient *peri*-operative endocrine care and counseling all overseen by the same provider or group of providers. Such dedicated teams may help reduce errors and tighten communication between specialties.

A unique strength of this study is the inclusion of patients who were told to drink to thirst or prescribed as-needed desmopressin due to ongoing concern for AVP-D. Previous fluid restriction studies often excluded these patients given their clinical complexity, but they remain a population at risk for hyponatremia due to the biphasic or triphasic response. The caregiver perspective is also invaluable given prior work linking informal caregiver lack of experience and readmission [20].

Limitations to this evaluation include the small sample size of interview participants overall given the relative rarity of disease for which TSS is indicated. To mitigate this, interviews were conducted until the same themes were being heard consistently and a diversity of voices regarding across demographics. Thus, the perspectives presented here are felt to be a representative sample from our institution. In general, interview themes also did not differ whether the patient's surgery was performed before or after the deployment of new discharge interventions. This is likely due to fluid restriction still being a key component of each period and verbal counseling being similar.

While quantitative analysis was not the focus of this study, improvements in readmission rates may be possible with the initiatives taken as part of this new protocol, which were aimed to achieve better patient understanding and adherence to fluid restriction. Larger analyses assessing the effect of fluid discharge protocols, including management of those with early AVP-D but triphasic response, are an area for additional research.

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Conclusions

Implementation of fluid restriction and discharge protocols following pituitary surgery relies on several patient and caregiver factors as well as multidisciplinary team coordination. Fluid restriction is feasible with the aid of guided patient education and fluid and urine output monitoring materials. For patients not on fluid restriction, instructions on outpatient desmopressin to take as needed remain confusing and should instead be provider-directed to avoid further sodium decline when patients are at risk for hyponatremia. Frequent contact with patients and caregivers by the neurosurgery and endocrinology teams after discharge is necessary to ensure patient safety and reduce readmissions.

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CRediT authorship contribution statement

Julia J. Chang: Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Alexis Amano:** Investigation, Methodology, Writing – original draft, Writing – review & editing. **Cati Brown-Johnson:** Formal analysis, Methodology, Writing – review & editing. **Olivia Chu:** Conceptualization, Methodology, Resources. **Victoria Gates-Bazarbay:** Conceptualization, Methodology, Writing – review & editing. **Erin Wipff:** Conceptualization, Methodology, Resources. **Samantha M.R. Kling:** Conceptualization, Writing – review & editing. **Mohamed Alhadha:** Conceptualization. **Juan Carlos Fernandez-Miranda:** Supervision. **Stacie Vilendrer:** Conceptualization, Formal analysis, Methodology, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jcte.2024.100336.

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