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Serum sodium and water imbalance after sellar, suprasellar, and parasellar surgeries: A prospective and observational study

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ABSTRACT

Background: Sodium and water imbalance is common after sellar, suprasellar, and parasellar surgeries. A wide variation in the diagnostic criteria of diabetes insipidus (DI) has been noted in literature. A highly variable incidence of DI and hyponatraemia has been reported. There is paucity of Indian studies. **Aims and Objectives:** The study was designed to evaluate serum sodium level and water imbalance after sellar, suprasellar, and parasellar surgeries. This was evaluated in terms of occurrence of hyponatraemia and central DI on day 1 and day 7 in the post-operative period. **Materials and Methods:** Patients of either sex, aged from 18 to 65 years, ASA physical status I-II, GCS score ≥13, with baseline normal electrolyte level, posted for elective neurosurgical procedures for sellar, suprasellar, and parasellar tumours, were included for this study after satisfying the inclusion and exclusion criteria. A convenient sampling of 50 patients was considered for this study. The primary outcome measures were to determine the incidence of hyponatraemia and central DI. Other adverse event and any requirement of desmopressin in the post-operative period were also noted. **Results:** In the present study, the majority (74%) of patients were 31–50 years. Female preponderance was noted with male: female ratio as 1:1.4. Out of 50 cases 41 (82%) had transcranial surgery and 9 (18%) had transphenoidal surgery. The incidence of sodium and water disturbances (SWD) was observed in 22% (11/50) patients. Out of these 11 patients, nine developed DI and two had hyponatremia on day 1 in the post-operative period. Both the abnormalities were found to recover on day 7. Only 1 patient (2%) required desmopressin. **Conclusion:** The incidence of SWD after sellar, suprasellar, and parasellar surgeries was found to be common (22%). The hyponatraemia and DI responded to the therapy and were transient in nature.

Key words: Diabetes insipidus; Hyponatremia; Pituitary; Sellar; Suprasellar; Parasellar; Surgeries

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INTRODUCTION

Disorders of sodium and water balance are common after sellar, suprasellar, or parasellar surgeries.[1] Several factors such as aberrant release of antidiuretic hormone (ADH) from the neurohypophysis, cortisol deficiency, abnormalities in the sympathetic innervation of hypothalamus secondary to the handling of hypothalamus or the pituitary stalk, or perioperative medications are related with this.[2-4]

Hypothalamo-hypophyseal axis is a strong regulator of body fluid and sodium metabolism.[2,5] (ADH, vasopressin), secreted from posterior pituitary has physiological effects on collecting duct of kidney, is one of the important hormones who maintain the sodium and water homeostasis in the body. Because sodium is the main constituent of plasma osmolality, these osmolality related disorders such as diabetes insipidus (DI) and syndrome of inappropriate ADH (SIADH) are typically characterized by hypernatremia and hyponatremia, respectively.[6]

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Hyponatremia after sellar/suprasellar surgeries has a complex pathophysiology and could be due to pituitary damage driving arginine vasopressin release and overall dysfunction of the osmoregulation.[7] Hypernatraemia is more common than hyponatraemia after transsphenoidal surgery. In the recent past (2013), a retrospective study[8] analyzing data of 129 surgical patients found that 53% of patients developed sodium imbalance and 22% of patients suffered from severe sodium imbalance in the post-operative period. About 35% of patients developed hypernatraemia (Na >145 mmol/L) with peak sodium levels at a median of 2 days (mean 2.3 days) following surgery, and 23 patients (18%) developed hyponatraemia ([Na^+] <135 mmol/L) with nadir sodium levels at a median of 6 days (mean 6.4 days) in the post-operative period. The incidence of the water balance disorders is variably reported from 60% to 70% in patients undergoing surgeries for sellar and suprasellar lesions.[9,10] In a recent study[11] on transcranial pituitary surgery, immediate post-operative DI was found in about 33.3% and persistent DI was noted in 12.6% of patients. Transient DI was the most frequent sodium and water disturbances (SWD) with a peak incidence of 57.4%,[1] on 2nd post-operative day (POD). Other studies[7,10] in the past reported about a wide variation of the entity between 10 and 80%. Delayed post-operative hyponatremia has been reported in 20% of patients in a delayed fashion with serum sodium reaching the lowest level around POD7.[5] Thus, a wide variation was noted in the reported incidence of sodium and water imbalance in the post-operative period after sellar and suprasellar surgeries. At the time of designing the present study, literature search had identified only two studies[12,13] performed in Indian scenario. Among those, one study[12] had reported DI to be the next common (14.8%), post-operative adverse event preceded by cerebrospinal fluid leak (CSF) (40%). The other study[13] reported the incidence of DI to be as high as in 58% of their patients. Hence, this prospective and observational study was designed to evaluate serum sodium level and water imbalance after sellar, suprasellar, and parasellar surgeries, given the highly variable reported incidence of DI and the paucity of studies involving Indian population. This was evaluated in terms of occurrence of hyponatremia and central DI on day 1 and day 7 in the post-operative period.

Aims and objectives

The aim of the study was to determine the incidence of abnormalities of sodium and water imbalance in the form of hyponatremia and central DI on day 1 and day 7 in the post-operative period after sellar, suprasellar, and parasellar surgeries. The primary outcome measures were determining the incidences of hyponatremia and central DI. Other outcome measures were to evaluate about occurrence of other adverse event and incidence of any requirement of desmopressin in the post-operative period.

MATERIALS AND METHODS

This prospective and observational study was conducted in the Institute of Postgraduate Medical Education and Research/S.S.K.M. Hospital, a Government Medical College, after obtaining the approval from the Institute's Ethics Committee. The present study was performed involving patients of either sex, aged from 18 to 70 years, qualifying to ASA physical status I-II, having GCS score ≥13 and normal baseline electrolyte profile, scheduled for elective neurosurgeries for sellar, suprasellar, and parasellar tumors. The patients were included for this study based on the inclusion and exclusion criteria and after obtaining written informed consent. The patients were managed in the neurosurgical ward and intensive care unit (ICU) set up as per their clinical conditions.

Exclusion criteria

The patients conforming to ASA physical status III-IV, and those with significant cardiac, renal, or liver diseases and those on long-term use of steroids, and diuretics were excluded from the study. Patients on antipsychotics were also excluded from the study. The patients who did not give consent were kept out of this study.

Sample size calculation

In the Indian scenario, in a prospective and observational study[13] of adult patients undergoing surgeries for suprasellar and sellar masses, post-operative DI was observed in 58% of patients. Sample size was calculated on the basis of formula for observational study.[14]

Sample size (n)=$([Z_{\alpha/2}]^2 \times p \times q]/d^2$ where $Z_{\alpha/2}=1.96$ (the standard normal variate at 5% type 1 error; $P<0.05$). P=Expected proportion in population based on the previous studies (past prevalence), here, it is 58%, and q=(100-p). d=Absolute error or precision – it is decided by the researcher. For this study, 20% of relative precision was assumed. Here d=20% of 58=11.6.

After substituting the values in the above formula, the sample size=$([1.96]^2 \times 58 \times 42]/(11.6)^2=69.5 \approx 70$ (approximated). From hospital records of the previous 3 years, the average case load was assessed and found to be approximate 40 cases per year, with some fluctuations in numbers. It was decided to observe 50 patients for this study on feasibility ground, keeping in mind the duration of the study.

A detailed pre-anestheic checkup was done before the day of surgery. On the day of surgery in the recovery

room, patient comes with 18 gauze intravenous cannula and intravenous fluid (normal saline) was given. Patient was connected to standard ASA monitors (NIBP, ECG, pulse oximeter, and temperature, $EtCO_2$). Before induction, arterial line was done after performing Allen's test. Continuous invasive hemodynamic monitoring was started to monitor stroke volume variation and cardiac output. Bispectral index (BIS) monitor was attached to the patient.

All patients were given injection (inj.) hydrocortisone 100 mg before induction as per Institute's surgical protocol. For the study design, patients receiving long-term steroids were not included in the study. However, receiving this single dose of steroids to every patient cannot be avoided due to the surgical protocol. Patients received no further doses of steroids. At the time of induction, patients received bolus fentanyl (2 mcg/kg) and infusion propofol through target-controlled infusion (TCI) pump (Schnider model, propofol 1%) with target concentration being 3–4 mcg/ml depending on demographic characteristics; and inj. rocuronium (0.9 mg/kg) bolus as a muscle relaxant to secure airway.

After intubation, central venous line was done. Intraoperatively anesthesia was maintained with IV infusion of propofol through TCI pump, with rate of infusion being adjusted as per hemodynamics (target MAP: 70–80 mmHg) after adequate fluid resuscitation as per goal directed fluid therapy (SVV<13%) and BIS value within 40–60. Propofol infusion was continued through TCI pump. Patients received inj. fentanyl IV bolus 0.5 mcg/kg when there was >30% increase in heart rate or BP. All patients received intravenous inj. paracetamol @15 mg/kg.

After completion of surgery, patients were transferred to neuro ICU irrespective of extubation status. On receiving the patients in neurosurgery ICU, baseline investigation such as complete blood count, renal function test, electrolytes, and blood glucose – all were sent. The vital parameters were monitored.

On the next day of surgery, i.e., on POD 1, blood sample were sent for measurement of serum sodium, serum glucose and BUN. On that occasion urine sample was also sent for analysis of urinary sodium and urinary glucose. The serum and urine sodium level was recorded for every patient on POD 1 and POD 7. The measured osmolality of serum and urine were recorded on POD 1 and POD 7. And then the Urine/Plasma osmolality ratio was calculated. Urine output monitoring was done using urinometer, and the 24-h urine output was noted every day in the post-operative period for treatment purpose, and values on day 1 and day 7 were recorded.

The demographic characteristics and clinical indications for surgery were recorded. Laboratory values for serum electrolytes, plasma and urine osmolality, urine sodium, and 24-h fluid balance from the immediate POD until discharge and follow-up was observed and followed. Necessary medical management plans were kept ready to address post-operative adverse events. As the physiological disturbance is often transient as per literature, a careful monitoring was done. An expectant and supportive management strategy was adopted in the patients in the present study as they were asymptomatic.

The outcome parameters were the incidence of hyponatremia and DI on POD 1 and POD 7. The patients were identified to have those entities on the basis of the following definitions. Hyponatremia was defined as serum concentration <135 mMol/L. In the literature[15-18] the majority of studies reporting on the incidence of post-operative DI do not provide uniform definitions, and a wide variation in the use of clinical and biochemical parameters was noted. In the present study, the diagnosis of DI was done on the basis of following working criteria[15] based on the feasibility ground: (i) Polyuria: the 24-h urine output amounting to 4 liter or more, (ii) increased plasma osmolality >300 mosm/kg, (iii) Urine osmolality <200 mosm/kg, and (iv) Urine/Plasma osmolality ratio <1. Thus, the number of patients having any hyponatremia or DI was noted. This was the primary outcome of the study.

Postoperatively, the patients received normal saline (0.9% sodium chloride solution) 6 hourly as intravenous (iv) fluid according to the Institute's protocol, and adjusted according to the clinical parameters and subsequent laboratory parameters that were monitored regularly. The different parameters (serum sodium, serum osmolality, urine sodium, urine osmolality, BUN, and blood glucose) were monitored regularly. Urine output was monitored hourly with urinometer. When a patient was diagnosed to have hyponatremia, the normal saline fluid was maintained and initially frusemide was used, and close clinical monitoring was done. However, in those patients who had high urine output (>250 mL/h for successive 3 h, and high serum sodium level, the DI is suspected. The iv fluid was changed to half-normal saline, and plain water was given through nasogastric tube. The amount of total fluid was adjusted to balance the high urinary output. A close vigil was maintained with regular serum sodium measurement and hourly urine output, to see any rising or decreasing trend of hypernatremia. When there was worsening trend of hypernatraemia despite conservative management, intranasal desmopressin was considered as one puff (10 mcg/puff) in both nostril and the patient was monitored closely. In the present study, it was given on the 2nd POD on seeing the uprise trend of hypernatremia

despite conservative management. No other adverse events were observed.

The following variables were measured on POD 1 and POD 7: Serum sodium, serum osmolality, urine sodium, and urine osmolality, and 24-h urine output. Based on the definitions, the patients were identified to have hyponatremia or DI, and it was recorded as number of patients.

Data were collected in the neurosurgical wards and neurosurgery ICU set up where patients were present in the post-operative period after sellar, suprasellar, and parasellar surgeries. Collected data were analyzed using appropriate software.

Statistical analysis plan

Data were summarized as number of patients and proportions. Those parameters which are continuous data are presented as Mean±Standard Deviation. Numbers of patients having different types of SWD have been presented as bar diagram.

RESULTS

The spanned over approximately 18 months, from April 2021 to September 2022. Data from all 50 patients who had their elective neurosurgical operative procedures for sellar, suprasellar, and parasellar tumors were available for analysis.

In our study, patients were aged from 18 to 70 years with mean age of 37.58±8.25 years. A majority of patients were the age group of 31–40 years and 41–50 years age groups (44% and 30%, respectively). In this study population (n=50), females were predominantly more in number than males. There were 21 (42%) males and 29 (58%) females (male: female ratio=1:1.4). The most common clinical presentation among this study population was headache (62%) and blurred vision (54%). Acromegalic features, menstrual abnormalities, and other presentations were seen in 20% of the cases (Table 1).

Size of tumor ranged from 1.1 cm to 4.8 cm. Prolactinoma was the most common type of tumor (36%), followed by non-functioning pituitary tumor (26%), meningioma (22%), somatotropic adenoma (6%), craniopharyngioma (4%), gonadotropin secreting tumor (4%), and suprasellar cyst, (Table 2). Out of 50 cases, 41 (82%) had transcranial surgery and 9 (18%) had transphenoidal surgery. Pituitary adenoma was the most prevalent suprasellar lesion (90%), (Table 2).

Pre-operative sodium level (mEq/L) was 137.48±2.02 (data not presented in the table). In the present study, incidence of SWD was 22%. Out of 50 cases, 11 had some kind of SWD. Out of 11 cases of SWD, nine had DI and two had hyponatremia on POD 1 (Table 3 and Figure 1).

Table 1: Demographic data and clinical presentation

Characteristics	Category	Number (proportion)
Sex	Male	21 (42)
	Female	29 (58)
Male: Female ratio		1:1.4
Mean age*		37.58±8.25
Age groups	18–30 years	9 (18)
	31–40 years	22 (44)
	41–50 years	15 (30)
	51–60 years	4 (08)
	61–70 years	0
Clinical presentation	Headache	31
	Blurred vision	27
	Acromegalic features	2
	Menstrual irregularities	1
	Others	10

Data are presented as number of patients (proportions) except that is marked with *sign which is displayed as mean±standard deviation

Table 2: Type of tumor and surgery

Characteristics	Category	Number (proportion) (%)
Type of lesion	Pituitary adenoma	45 (90)
	Non-pituitary lesion	5 (10)
Type of tumor	Prolactinoma	18 (36)
	Non-functioning pituitary tumor	13 (26)
	Meningioma	11 (22)
	Somatotropic adenoma	3 (6)
	Craniopharyngioma	2 (4)
	Gonadotropin secreting tumor	2 (4)
	Suprasellar cyst	1 (2)
Type of surgery	Transcranial	41 (82)
	Trans-sphenoidal	9 (18)

Size of tumor was ranged from 1.1 cm to 4.8 cm

Different variables of those patients diagnosed as hyponatremia (n=2) and those diagnosed as having DI (n=9) were depicted in the following table to have an apparent comparative impression (Table 4). However, the values were not analyzed as it was not designed to find any such.

The hyponatremia and DI as documented on day 1 were found to recover on day 7 (Table 4). The serum sodium and serum osmolality in both the hyponatremia and DI patients recovered on day 7 (Figure 2a and b). Similarly, urinary sodium and osmolality were found to normalize on day 7 (Figure 2c and d). Thus, in our study cases, it was transient DI and hyponatremia patients also responded adequately to the treatments. Out of 50 cases in the present study, only one patient (2%) required desmopressin.

Table 3: Incidence of SWD

Characteristics	Category	Number (proportion)
SWD	Present	11 (22)
	Absent	39 (78)
SWD (n=11)	Hyponatremia	2 (4)
	DI	9 (18)

SWD: Sodium water disturbances, Abnormalities as detected on postoperative day (POD) 1 is presented here. The entities recovered to near normal on POD 7, DI: Diabetes insipidus

Table 4: Post-operative changes in sodium and osmolality

Changes on POD	POD 1	POD 7
Serum sodium level (mEq/L)		
Patients with hyponatremia (n=02)	123.00±7.07	136.50±3.53
Patients with diabetes insipidus (n=09	146.77±1.64	139.11±3.82
Serum osmolality (mOsm/kg)		
Patients with hyponatremia (n=02)	256.93±12.21	283.93±5.14
Patients with diabetes insipidus (n=09	304.77±3.11	289.44±7.72
Urine sodium level (mEq/L)		
Patients with hyponatremia (n=02)	16.50±2.12	20.50±0.70
Patients with diabetes insipidus (n=09	18.44±4.53	25.33±3.00
Urine osmolality (mOsm/kg)		
Patients with hyponatremia (n=02)	43.93±2.31	51.93±0.50
Patients with diabetes insipidus (n=09)	48.11±8.84	61.89±6.54
Urine output		
Patients with diabetes insipidus (n=09)	4.24±0.28	1.9±0.73

Data are presented but not analyzed or compared because it was not designed in such a way. POD: Post-operative day

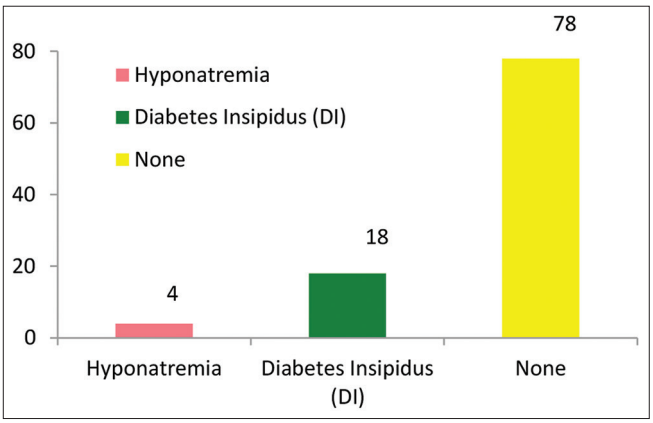

Figure 1: Types of sodium water disturbances as found in this study

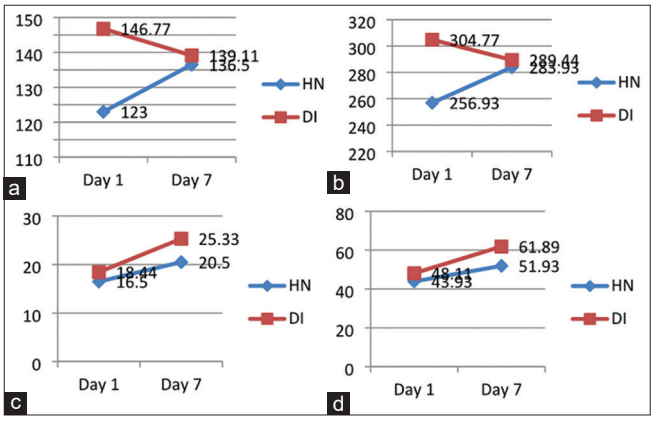

Figure 2: Serum and urine parameters on post-operative day 1 and 7. Figure 2a, 2b, 2c and 2d depicts about changes in serum sodium, serum osmolality, urine sodium and urine osmolality, respectively

DISCUSSION

DI and hyponatremia are important common complications in the immediate postoperative period following sellar, suprasellar, and parasellar surgery. DI can occur in 16–38% of patients.[9,10] It usually occurs during the first or second POD and usually resolves completely within a period of 10 days or so.[10] The majority of hyponatremia is delayed in presentation and is secondary to SIADH. The incidence of hyponatremia varies between 1.7% and 28%.[8,9,19] It occurs as early as day 4 to as late as day 14 postoperatively, with a nadir around 7 days.[3,8,9] Fortunately, hyponatremia is most often mild, asymptomatic, and self-limiting, resolving within around 5 days.

In the present study (n=50), patients had elective neurosurgical operative procedures for sellar, suprasellar, and parasellar tumors. The majority of patients were in the 31–50 years of age and a female preponderance was noted. The most common clinical presentation among study population was headache and blurred vision. In the present study, 41 patients (82%) had transcranial surgery and 9 patients (18%) had transphenoidal surgery, Pituitary adenoma was the most prevalent suprasellar lesion (90%).

In the recent past (2017), Kiran et al.,[1] evaluated the frequency of SWDs in patients (n=115), undergoing sellar, suprasellar, and parasellar surgery. In their study, the most prevalent suprasellar lesion was pituitary adenoma (91.3%) of which mostly was non-functioning (73%). About 86% of patients underwent surgery through transsphenoidal approach. The study of Kiran et al.,[1] showed that the median age of their participants was 40 years (interquartile range, 32–52 years), and the majority (61.7%) were males. Most of their patients presented with symptoms of headache and visual disturbances combined (31.3%), followed by headache with other symptoms (18.4%). Some of them had various combinations of headache, visual disturbance, and menstrual irregularities (7%). Some patients complained of nausea and vomiting (5.3%). Kiran et al.,[1] reported that pituitary adenoma was the most prevalent suprasellar lesion (91.3%), mainly non-functional.

In the present study, the incidence of sodium and water imbalance was noted in 11 patients (22%). Out of those 11 patients, hyponatremia was found in two patients and DI was diagnosed in 9 patients (18%). All the abnormalities of sodium and water imbalance that was found on POD1 and recovered mostly on day 7 in the post-operative period.

Venkatapura et al.,[20] reported about 66% incidence of hyponatremia during hospital stay in patients with supratentorial tumors (non-sellar/suprasellar). Moreno et al.,[21] reported that the incidence of hyponatremia to be 18% and overall prevalence of water and electrolyte disorders was 30.5% in their study population (n=203). However, Ghirardello et al.,[22] reported a high incidence (90%) of sodium and water imbalance where a more extended periods of time (up to 6 months) were reported in a prospective analysis of patients who had surgery for craniopharyngioma. In the study of Kiran et al.,[1] hyponatremia accounted for 31.9% of cases (isolated hyponatremia and DI with hyponatremia combined), resolving without a particular management strategy. In that study, six patients had sodium <135 mEq/L at presentation, with the lowest, at 127 mEq/L, requiring hypertonic (3%) saline on day 1. In the study of Kiran et al.,[1] transient DI occurred from days 1 to 6, peak on day 2. Only two patients developed SIADH between days 7 and 14, and afterward resolved. Permanent DI and SIADH were rare. They concluded that transient DI is the most common post-operative SWD. Chowdhury et al.,[12] found the incidence of DI to be the second next common complication (14.8%) in their series, the most common being the CSF leak (40%). However, the DI was transient in nature. The authors[12] commented that if not treated, DI can result in life-threatening fluid and electrolyte imbalance.

In a multi-center, retrospective, and cohort study, Carampatana-Jandug et al.,[23] reported that the most common immediate post-operative complications after pituitary surgery were DI (22.5%), followed by intracranial hemorrhage/hematoma and CSF leak. In another recent single-center retrospective review (n=22), Ugwuanyi et al.,[24] reported that after surgery for pituitary adenoma, the major complications were DI (59.1%) and CSF leak (22.7%). Other less frequent complications in their patients were dyselectrolytemia, intraventricular hemorrhage, and hypopituitarism.

In the present study, hyponatremia was found in 2 patients (4%) on day 1 and they recovered mostly at day 7 of post-operative period. However, it was not possible to observe for a longer period as it was beyond the scope of the study (not designed in that way).

The incidence of delayed hyponatremia is not uncommon and this entity was found in 22.6% of patients with non-functioning pituitary tumor who underwent endoscopic transsphenoidal surgery.[25] Old age,[25] long surgery time,[25] low BMI[26] all were associated with the development of delayed hyponatremia in such category of patients. While hyponatremia on POD 1–2 has been reported to be associated with development of delayed hyponatremia in some study,[25] the contrast observations[26] do exist suggesting that mere alterations in immediate post-operative sodium levels may not predict delayed post-operative hyponatremia.

Hossain et al.,[27] reported that post-operative serum sodium imbalance after transsphenoidal surgery for sellar and suprasellar space occupying lesions occurred in 60% of their study patients (n=30). Out of those patients, 40% developed hypernatremia, 13.3% developed hyponatremia and only 6.7% suffered the combined imbalance. Peak incidence of hyponatremia occurred on 3rd post-operative day and hypernatremia occurred at 1st POD. Hypernatremia has been reported to be more common than hyponatremia after transsphenoidal surgery.[26]

The water and electrolyte disturbances in the majority of patients undergoing transsphenoidal adenectomy were reported to be mostly transient.[10] However, Hussain et al.,[26] reported that the overall prevalence of hyponatremia in their study was 22% (82 occurrences for 373 procedures), of which 15% occurred after discharge from the hospital. Hence, long-term follow-up is important.

Nayak et al.,[28] in their study (n=271) reported the incidence of DI to be 16.6%, with only 4% having permanent DI. Pituitary adenoma patients presenting with visual abnormalities, suprasellar extension, or large tumors are said to be at higher risk of developing DI in the post-operative period.[26]

In the present study, every patient had required steroid during the study. Desmopressin was given mostly on an as need basis, to avoid iatrogenic hyponatremia through the oral or subcutaneous route. Kiran et al.,[1] used steroids immediately after the surgery with subsequent tapering as an outpatient basis.

Limitations of the study

There are certain limitations of the present study. First, the sample size was low due to less case load, a feasibility ground. Second, the specific gravity could not be measured and hence, it was not used as diagnostic criteria for DI, and we have used alternative set of criteria for identifying the said entity. The study was not designed with long-term follow-up to diagnose the cases of persistent DI. If it could have been done, a larger prevalence of SWD might have been detected. Patients with underlying renal, hepatic, and cardiac diseases were not included in the study. Similarly,

patients with adrenal insufficiency and hypothyroidism were not included for which it is not possible to understand the effect of those comorbidities on hyponatremia and water imbalance. Measurement of ADH was also not possible due to logistic problem.

CONCLUSION

The incidence of SWD in the patients undergoing sellar, suprasellar, and parasellar surgeries is common (22%). Although hyponatremia is depicted as the most common entity after neurosurgery, we observed DI more frequently than hyponatremia in our sample population. The hyponatremia and DI responded to the therapy, transient, and self-limiting.

REFERENCES

1. Kiran Z, Sheikh A, Momin SN, Majeed I, Awan S, Rashid O, et al. Sodium and water imbalance after sellar, suprasellar, and parasellar surgery. Endocr Pract. 2017;23(3):309-317.
   https://doi.org/10.4158/EP161616.OR
2. Antunes-Rodrigues J, de Castro M, Elias LL, Valença MM and McCann SM. Neuroendocrine control of body fluid metabolism. Physiol Rev. 2004;84(1):169-208.
   https://doi.org/10.1152/physrev.00017.2003
3. Zada G, Liu CY, Fishback D, Singer PA and Weiss MH. Recognition and management of delayed hyponatremia following transsphenoidal pituitary surgery. J Neurosurg. 2007;106(1):66-71.
   https://doi.org/10.3171/jns.2007.106.1.66
4. Schreckinger M, Szerlip N and Mittal S. Diabetes insipidus following resection of pituitary tumors. Clin Neurol Neurosurg. 2013;115(2):121-126.
   https://doi.org/10.1016/j.clineuro.2012.08.009
5. Hasegawa H, Shin M, Makita N, Shinya Y, Kondo K and Saito N. Delayed postoperative hyponatremia following endoscopic transsphenoidal surgery for non-adenomatous parasellar tumors. Cancers (Basel). 2020;12(12):3849.
   https://doi.org/10.3390/cancers12123849
6. Loh JA and Verbalis JG. Disorders of water and salt metabolism associated with pituitary disease. Endocrinol Metab Clin North Am. 2008;37(1):213-234, x.
   https://doi.org/10.1016/j.ecl.2007.10.008
7. Hannon MJ, Finucane FM, Sherlock M, Agha A and Thompson CJ. Clinical review: Disorders of water homeostasis in neurosurgical patients. J Clin Endocrinol Metab. 2012;97(5):1423-1433.
   https://doi.org/10.1210/jc.2011-3201
8. Staiger RD, Sarnthein J, Wiesli P, Schmid C and Bernays RL. Prognostic factors for impaired plasma sodium homeostasis after transsphenoidal surgery. Br J Neurosurg. 2013;27(1):63-68.
   https://doi.org/10.3109/02688697.2012.714013
9. Adams JR, Blevins LS Jr., Allen GS, Verity DK and Devin JK. Disorders of water metabolism following transsphenoidal pituitary surgery: A single institution's experience. Pituitary. 2006;9(2):93-99.
   https://doi.org/10.1007/s11102-006-9276-2
10. Kristof RA, Rother M, Neuloh G and Klingmuller D. Incidence, clinical manifestations, and course of water and electrolyte metabolism disturbances following transsphenoidal pituitary adenoma surgery: A prospective observational study. J Neurosurg. 2009;111(3):555-562.
    https://doi.org/10.3171/2008.9.JNS08191
11. Wang S, Li D, Ni M, Jia W, Zhang Q, He J, et al. Clinical predictors of diabetes insipidus after transcranial surgery for pituitary adenoma. World Neurosurg. 2017;101:1-10.
    https://doi.org/10.1016/j.wneu.2017.01.075
12. Chowdhury T, Prabhakar H, Bithal PK, Schaller B and Dash HH. Immediate postoperative complications in transsphenoidal pituitary surgery: A prospective study. Saudi J Anaesth. 2014;8(3):335-341.
    https://doi.org/10.4103/1658-354X.136424
13. Simon SK, Pavithran PV, Asirvatham AR, Ayyadurai R and Parasuram A. Disorders of water balance following sellar and suprasellar surgeries: Patterns, determinants and utility of quantitative analysis. Indian J Endocrinol Metab. 2018;22(2):191-195.
    https://doi.org/10.4103/ijem.IJEM_647_17
14. Charan J and Biswas T. How to calculate sample size for different study designs in medical research? Indian J Psychol Med. 2013;35(2):121-126.
    https://doi.org/10.4103/0253-7176.116232
15. Edate S and Albanese A. Management of electrolyte and fluid disorders after brain surgery for pituitary/suprasellar tumours. Horm Res Paediatr. 2015;83(5):293-301.
    https://doi.org/10.1159/000370065
16. Almalki MH, Ahmad MM, Brema I, Almehthel M, AlDahmani KM, Mahzari M, et al. Management of diabetes insipidus following surgery for pituitary and suprasellar tumours. Sultan Qaboos Univ Med J. 2021;21(3):354-364.
    https://doi.org/10.18295/squmj.4.2021.010
17. De Vries F, Lobatto DJ, Verstegen MJ, Van Furth WR, Pereira AM and Biermasz NR. Postoperative diabetes insipidus: How to define and grade this complication? Pituitary. 2021;24(2):284-291.
    https://doi.org/10.1007/s11102-020-01083-7
18. Harrois A and Anstey JR. Diabetes insipidus and syndrome of inappropriate antidiuretic hormone in critically ill patients. Crit Care Clin. 2019;35(2):187-200.
    https://doi.org/10.1016/j.ccc.2018.11.001
19. Hensen J, Henig A, Fahlbusch R, Meyer M, Boehnert M and Buchfelder M. Prevalence, predictors and patterns of postoperative polyuria and hyponatraemia in the immediate course after transsphenoidal surgery for pituitary adenomas. Clin Endocrinol (Oxf). 1999;50(4):431-439.
    https://doi.org/10.1046/j.1365-2265.1999.00666.x
20. Venkatapura RJ, Jena SS, Christopher R and Bhat DI. High incidence of hyponatremia in patients operated for nonsellar/suprasellar supratentorial tumors-a prospective observational study. J Neuroanaesthesiol Crit Care. 2021;8(3):192-196.
    https://doi.org/10.1055/s-0041-1730043
21. Moreno JM, Fuentes ED, Moreno EV, Ruíz PJ, Gómez CM, Gutiérrez AP, et al. Postoperative water and electrolyte disturbances after extended endoscopic endonasal transsphenoidal surgery. Front Endocrinol (Lausanne). 2022;13:963707.
    https://doi.org/10.3389/fendo.2022.963707
22. Ghirardello S, Hopper N, Albanese A and Maghnie M. Diabetes insipidus in craniopharyngioma: Postoperative management of water and electrolyte disorders. J Pediatr Endocrinol Metab. 2006;19 Suppl 1:413-421.
23. Carampatana-Jandug C, Esguerra J, Panilagao G, Mejia A, Rama J and Bilocura F. In-hospital postoperative complications in patients with pituitary adenoma who underwent pituitary

surgery from January 2010 to December 2015: A multicenter study. J Endocrinol Metab. 2017;7(4):122-130.
https://doi.org/10.14740/jem429w

24. Ugwuanyi CU, Anigbo AA, Salawu MM, Jibrin P, Okpata CI, Ayogu OM, et al. Complications of surgery for pituitary adenomas-a retrospective review of single institutional experience. Tech Neurosurg Neurol. 2022;4(5):TNN.000596.
https://doi.org/10.31031/TNN.2022.04.000596
25. Yoon HK, Lee HC, Kim YH, Lim YJ and Park HP. Predictive factors for delayed hyponatremia after endoscopic transsphenoidal surgery in patients with nonfunctioning pituitary tumors: A retrospective observational study. World Neurosurg. 2019;122:e1457-e1464.
https://doi.org/10.1016/j.wneu.2018.11.085
26. Hussain NS, Piper M, Ludlam WG, Ludlam WH, Fuller CJ and Mayberg MR. Delayed postoperative hyponatremia after transsphenoidal surgery: Prevalence and associated factors. J Neurosurg. 2013;119(6):1453-1460.
https://doi.org/10.3171/2013.8.JNS13411
27. Hossain MM, Kadir ML, Jahan NA, Hasan MM, Uddin KH, Saha MK, et al. Correlation between the size of tumour with early postoperative serum sodium imbalance in sellar and suprasellar space occupying lesion after transsphenoidal surgery. Bang J Neurosurg. 2020;10(1):82-91.
https://doi.org/10.3329/bjns.v10i1.49167
28. Nayak P, Montaser AS, Hu J, Prevedello DM, Kirschner LS and Ghalib L. Predictors of postoperative diabetes insipidus following endoscopic resection of pituitary adenomas. J Endocr Soc. 2018;2(9):1010-1019.
https://doi.org/10.1210/js.2018-00121

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