Original Article

Disorders of Water Balance Following Sellar and Suprasellar Surgeries: Patterns, Determinants and Utility of Quantitative Analysis

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Abstract

Background and Objective: The primary objective of this study was to evaluate the application of principles of quantitative analysis to assess disorders of water balance following surgeries for sellar and suprasellar masses and also to investigate potential factors influencing the occurrence and course of these disorders. **Materials and Methods:** A total of 36 consecutive adult patients who underwent surgery for sellar and suprasellar masses between 2014 and 2015 were prospectively followed up in this observational study. Twenty-one patients had complete laboratory parameter records for quantitative analysis. Clinical parameters, daily fluid balance, and sodium balance were calculated based on the fluid chart and the estimation of sodium concentration of fluids and urine. Classical Edelman equation was used to predict the sodium values. Time course of these disorders and association with etiological and other clinical parameters were assessed. Standard institutional protocol was used in the management of patients studied. **Results:** Comparison between predicted values of quantitative analysis and observed values of sodium showed that 80-95% of the observed readings on various days showed concordance with calculated reading, with <5% error. 77.7% manifested at least one episode of dynatremia relating to water balance disorder during the postoperative period. Postoperative diabetes insipidus (DI) observed in 58% of patients, whereas syndrome of inappropriate antidiuretic hormone secretion observed in 47% of patients. Both DI and SIADH in different time points were noticed in 28%, and classical triple phase response was seen in 2.7%. Nearly 83% manifested one episode of dynatremia relating to water balance disorder during the post-operative period. Prolonged DI was noted in 11% and no case of cerebral salt wasting was observed in any of the patients studied. **Conclusion:** We observed high degree of correlation between the predicted and observed sodium values. Quantitative analysis in the management of patients with disorders of water balance in postsurgical settings in neurosurgery has the potential for improving clinical care.

Keywords: Diabetes insipidus, hypernatremia, syndrome of inappropriate antidiuretic hormone, water balance

Introduction

The incidence of the water balance of disorders is known to vary from 60% to 70% in patients undergoing surgeries for sellar and suprasellar lesions.[1,2] Considerable morbidity is associated with these conditions in the postoperative settings due to dysnatremia. Hyponatremia is frequently encountered in patients with neurological diseases[1,2] which is more common than hypernatremia. The most common etiology of hyponatremia in these patients is the syndrome of inappropriate ADH secretion. Other causative factors include secondary adrenal insufficiency and increased use of diuretics. Hyponatremia noticed in most cases is a direct result of the surgery though[3] ADH independent mechanism may also play a role.[4] Rarely, it may be be initiated by a postoperative complication like pneumonia as well. Many patients undergoing neurosurgical procedures of the sellar and suprasellar areas are found to develop a triple phase response characterized by early

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diabetes insipidus (DI), followed by a period of inappropriate secretion of ant diuretic hormone (SIADH) and recurrence of DI.[2] DI lasting >3 months was often defined as prolonged DI.

The definition and criteria for the diagnosis of SIADH is well agreed on. However, the factors associated with this disorder in neurosurgical patients are less elucidated.[5] Less common is the enigmatic condition, cerebral salt wasting (CSW). Distinguishing hyponatremia due to CSW from the more familiar syndrome of inappropriate SIADH can be quite difficult. In the absence of a clearly documented estimate of urine volume depletion and high urine output, diagnosis of CSW becomes difficult. The management approach to these disorders is again not uniform. It is apparent that there is a lack of adequate data regarding factors associated with these disorders, efficacy of the treatment options and outcome.

Attempts have been made in predicting changes in Na^{++} concentration based on changes in the administered fluids.[6] Especially this is very important to decide on the volume, type of fluids and also the amount of sodium to be given to effect proper correction of dysnatremia. Most of the widely used methods consider the body as a closed system and use imperfect formulae to predict changes in water and sodium[7] concentration. Most of the time, results are less than satisfactory.

This study envisages to assess the accuracy of quantitative analysis in predicting sodium value as there is not much data available from the Indian subcontinent.

Materials and Methods

We sought to do a prospective observational study of adult patients (>17 years) undergoing surgeries for suprasellar and sellar masses. The primary objective of this study was to apply the principles of quantitative analysis[8,9] to try and predict the sodium values starting from the first postoperative day. Secondary objectives were to identify the patterns, duration, and determinants of SIADH and DI postsurgery.

The quantitative analysis principle is based on the Edelman equation which reads as:

Serum Na concentration = $(1.11\ [Na_e + K_e]/T.B.W) - 25.6$[10] (E)

where Na_e is total exchangeable sodium, K_e is total exchangeable potassium and TBW is total body water.

A modified version of the equation which ignores the Y intercept and slope is used to frame the simplified formulae like the Adrogue Madias formula[7] which takes into account the volume of infusate but considers the body as a closed system. One of the problems with the clinical application of the Edelman equation is the exchangeable Na and K concentrations which cannot be estimated. It is reasonable to deduce that if the patient is stable and having normal Na concentration on day 0 (before surgery), then exchangeable Na + k is simply the product of (current Na + 25.6) * TBM. TBW was taken as 0.6 × body weight expressed in liters. Daily fluids including oral, ryles tube, and intravenous fluids are quantitated along with Na intake in consultation with the Department of dietetics. Daily Na balance was calculated as previous day's exchangeable Na minus average of the two consecutive day's urine spot Na multiplied by urine output. Ideally, 24 h urine Na should be used, but it was impractical to get 24 h urine collection of all these patients every day and hence the approximation of taking an average of urine Na as on consecutive morning multiplied by the intervening day's urine output. In patients with normokalemia potassium, output is usually equal to input and hence, potassium was ignored. None of the patients included in the study has persistent hypokalemia during their hospital stay. All the patients were on stress or replacement doses of hydrocortisone.

($E_{MB)-}$ Massbalance of electrolytes arrived at by the formula:

$(Na + K)_{Input\ minus}\ (Na + K)_{Output}$

Since K_{input} minus K_{Output} zero is the most clinical situation, Na content of input and output was used to make calculations. To illustrate the calculations for urine Na output on day1, an average of urine spot Na s on day 1 and day 2 is taken and multiplied by urine output on day 1. This will partially take care of the variability of Na over days and its effect on 24 h urine Na.

V_{MB} -water balance

$Fluid_{input}$ minus $Fluid_{output}$

Input of fluids from solid-fluid intake and metabolic generation of water in the body were ignored as most of the cases they balance out with the insensible losses. Calculations were made using equation (E) as the exchangeable electrolytes (Na e + K e) can be calculated every day as previous days $(Na_e + K_e) + E_{MB.}$ After the first day V mb ie water balance, which can be negative or positive was added to (0.6 x body weight) to calculate the total body water.

A total of 36 consecutive patients who underwent sellar/suprasellar surgeries were included in the study. Of these from 21 patients had complete data for quantitative analysis. Patterns of water balance disorder, duration, and determinants of water balance disorders were noted.

Statistical analysis

The analysis was performed using IBM SPSS 20.0 Version. Apart from the descriptive data, the correlation between the different clinical parameters and the incidence of disorders of water balance was calculated. Association in the various categorical variables was done using Chi-square;

Table 1: Details of pattern of water balance disorder

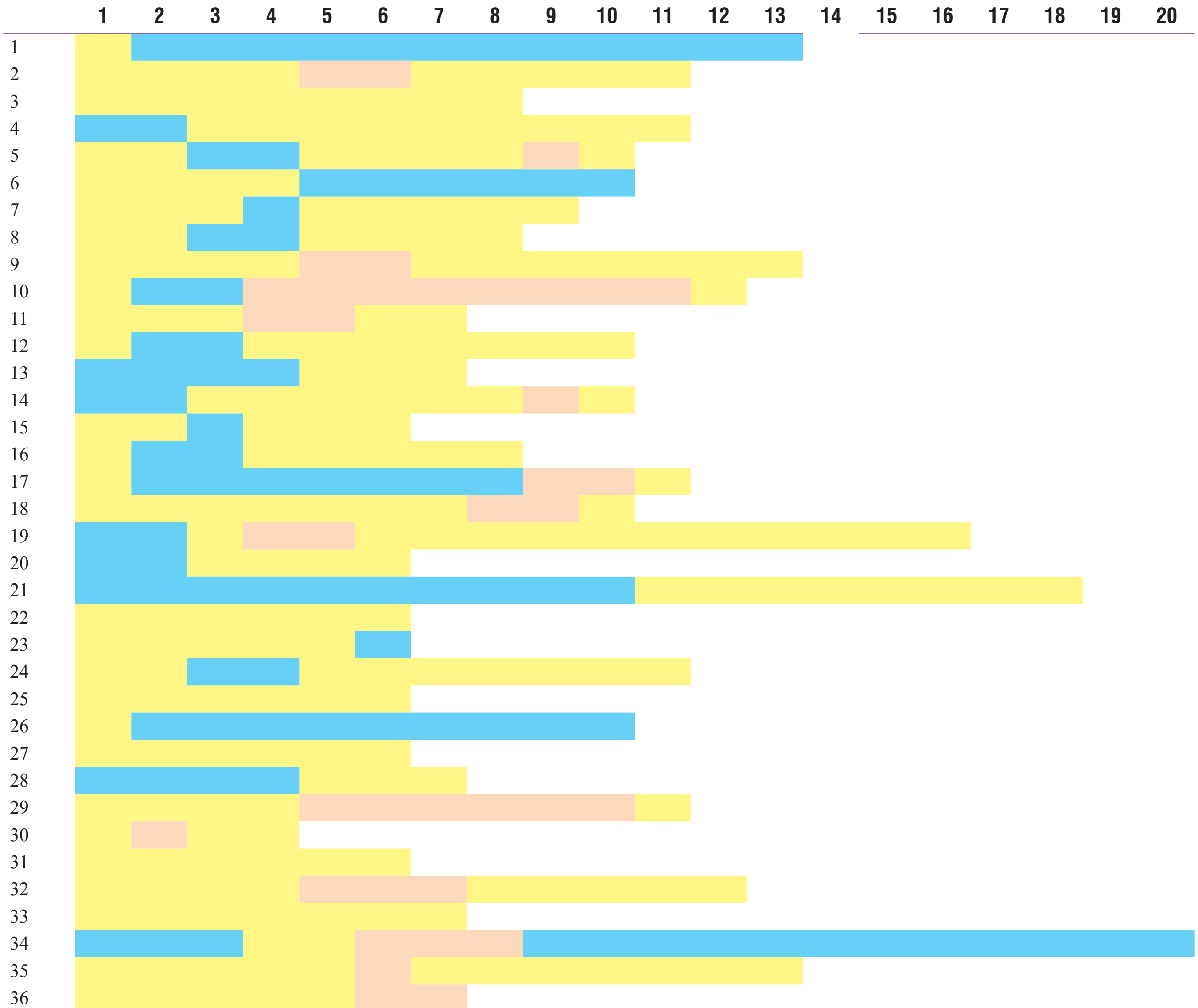
Pattern	Number (%)
No disorder	6 (16.6)
DI alone	15 (41.6)
SIADH alone	9 (25)
DI followed by SIADH	5 (13.8)
DI SIADH DI (Triple phase response)	1 (2.7)

Table 2: Sodium values on the day after surgery-comparison quantitative analysis based values and observed values

Number of patients	1st day		2nd day		3rd day		4th day		5th day		6th day		7th day		8th day		9th day		10th day	
	Exp Na	Act Na	Exp Na	Act Na	Exp Na	Exp Na	Act Na	Act Na	Exp Na	Act Na	Exp Na	Act Na	Exp Na	Act Na	Exp Na	Act Na	Exp Na	Act Na	Exp Na	Act Na
1	140.4	139.5	145.3	141.7	142.1	150	145	143.9	144	149.7	150	145	145.1	143	142.9	142.2	144.7	145.5	149.2	148.1
2	140	142.9	150.3	144.9	140.1	123.9	123.9	145.5	145.5	142.1	123.9	123.9	127.9	130.4	134.3	140.2	140.3	137.7	136.1	136.8
3	143.7	141.2	142.4	137	141.3	141.6	140.5	136.9	144.6	143.7	141.6	140.5	137.3	141.4	139.9	139.6	125.7	131.9	133.3	137.1
4	145.4	143.4	142.7	140.3	139.9	151.4	146.7	142.1	144.8	142.6	151.4	146.7	132.4	133.1	128.7	132	129.3	124	135.1	134.2
5	135.7	138.9	145.7	143.4	142.5	137.2	142.8	145	143.8	141.7	137.2	142.8	136.3	133.9	139.8	141.9	141.9	142.7	131	133
6	138.5	138.9	143.7	141.9	142.2	119	123.6	147.9	141.8	137.6	119	123.6	143.2	139.1	144.2	136.7	140.9	139.2	140.8	134
7	128.7	127.7	138.8	138	150.4	138.7	142.3	140.3	148.6	144.9	138.7	142.3	128.7	133.9	145.2	143	130.5	131	133.4	131.4
8	135.9	141	145.3	146.4	154.9	143.6	144.3	141.5	141.3	141.1	143.6	144.3	137.5	134.5	142.9	141.5	123.4	126.7	136.9	139.7
9	139.3	135.9	155.4	157.1	148.9	141.8	140	140.5	140.4	142.1	141.8	140	143.9	144.6	150.1	148	144.8	139	148.2	146.7
10	153	154.1	152.1	155	139.1	142	143.4	151.5	140.6	139.8	142	143.4	140.1	144.7	132.1	134.4	150.2	149.9	139.3	137.3
11	142.4	139.8	135.9	141	144.2	140.2	139.4	140.4	151.5	147.6	140.2	139.4	147.3	142.3	139.9	136.2	139.9	140.6	136.8	140
12	146.1	141	138.4	138.9	145.6	136.6	135.7	141.8	143.6	141.8	136.6	135.7	135.5	132.3	152.3	148.8	142.3	142.4		
13	145.6	146.4	140.3	142.9	143.5	135	138.4	144.8	139.6	140.9	135	138.4	136.1	139	149	144.5	131.1	137.4		
14	142.1	143.6	145.7	142.9	138.5	137.9	139.4	145.3	129.5	127.3	137.9	139.4	139.8	137.7	129.3	123.8				
15	148.3	146.7	139.3	135.9	139	150.8	152.8	151.6	148.6	146.7	150.8	152.8	143.9	137.1	138.6	134.1				
16	142.7	141.9	140.0	141.5	141.6	146.3	146.3	142.5	144.8	143.3	146.3	146.3	153.6	153.9						
17	142.6	141.4	142.5	139.8	143.3	143.2	140.3	135.6	138.4	140.4	143.2	140.3	135.2	140.5						
18	150.5	144.9	147.6	146.7	152.6	137.1	139.1	138.8	133.5	136.4	137.1	139.1	136.6	137						
19	142.4	137	153.2	154.1	140.9	134.9	135.4	140.9	134.7	135	134.9	135.4	122.7	122.2						
20	145.7	141.7	144.6	143.4	141	124.3	124.2	143.6	135.8	139.4	124.3	124.2	133.9	136.6						
21	140.4	139.5	146.3	141	136.6	135.9	136.4	141.2	138	142	135.9	136.4	136.6	137.4						
P	0.097		0.105		0.799		0.156		0.578		0.503		0.950		0.137		0.825		0.864	
Mean	1.08±2.86		1.07±2.90		0.15±2.70		0.87±2.69		0.35±2.81		0.40±2.72		0.53±3.76		0.94±3.62		0.30±3.48		0.16±3.08	

Exp Na is calculated sodium valueAct, Na is observed sodium value

Table 3: Details of the time course of disorders of water balance in the study population



DI (Na >145 or polyuria), SIADH (<130), Normal. Last date is the date of discharge

Comparison between continuous variables was performed using Mann–Whitney U-test.

Results

A total of 36 adults were followed up during their hospital stay. The baseline characteristics are mentioned below.

Age - 46 (17, 73), sex - m:f (16:20), pituitary adenoma (27), craniopharyngioma (6), sellar meningioma (3).

Preoperative DI or SIADH was not observed in any patient. Postoperative DI was observed in 21 (58%) patients whereas SIADH was observed in 15(42%) patients. Ten (28%) patients manifested both DI and SIADH. Classical triple phase response was seen in only 1 (2.7%) patient. A total of 30 patients (83%) of patients manifested at least one episode of dynatremia related to a disorder of water balance during their postoperative period. Prolonged DI was noted in 4(11%) patients. There was no case of CSW in the group of patients studied.

The median duration of DI and SIADH were 3 (1, 11) and 4 (2, 6) respectively. The median time of onset of SIADH was day 5 (4, 9) and duration was 2 days. No patient developed hyponatremia after 13 days postsurgery. Details of patients experiencing disorders of water balance are depicted in Table 1.

Central hypothyroidism and craniopharyngioma were the only two factors which were found to be significantly associated with the incidence of DI ($P < 0.05$). There was no significant association found between DI and other factors such as gender, age, and testosterone levels, and panhypopituitarism. The presence of central hypothyroidism was more in patients with DI ($P = 0.005$). Male gender was found to be associated with higher incidence of SIADH ($P = 0.006$). The incidence of SIADH was also found to be higher in the older age group. Central hypothyroidism, hypogonadism, panhypopituitarism, and craniopharyngioma were not found to be associated with the incidence of SIADH.

The result of the primary objective, i.e., comparison between the predicted and observed sodium values of the 21 patients with complete data is available in Table 2. The correlations coefficients for different consecutive days are 0.853, 0.859, 0.835, 0.756, 0.851, 0.949, 0.865, 0.867, 0.901, and 0.848. Details of the time course of disorders of water balance in the study population are given in Table 3.

Discussion

The reported prevalence of the disorders of water balance in this study is similar to that reported in previous literature. DI was noticed in 58% of patients as compared to 30%[11] that described in available literature. The classical triple phase response was seen in only one patient. DI was associated with male sex and younger age in previous studies.[12]

As has been noticed in the present studies, there was a higher prevalence of SIADH and both SIADH and DI in patients of the male sex. The higher rate of incidence of DI was also observed in patients with central hypothyroidism. The higher incidence of DI noticed in suprasellar surgeries[3] is in agreement with available literature. Risk of hyponatremia was seen until the end of the 2nd week. Thing finding underscores the need to continue monitoring Sodium until the end of the 2nd week in patients who are discharged in the 1st week postsellar or suprasellar surgery.

The observation which evoked much interest in this study is the value of quantitative analysis in predicting Na shifts. As can be seen in Tables 1 and 2, in >80% of cases, there was a good agreement between the predicted and observed values. Current practices do not give much attention to the rigorous quantitative analysis of fluid and electrolyte balance. Correction of dysnatremia is guided by closed system formulae as detailed in the review of the literature. Inaccuracies relating to these formulae partly arise from their neglect of the output part, particularly in relation to electrolytes. As has been clearly revealed in this study, the rigorous quantitative analysis will help in predicting Na levels in the patients afflicted with disorders of water balance. A key element of this analysis is the estimation of urine Na levels which is often neglected in clinical practice. Systematic monitoring of input, output volumes and electrolytes parameters will help in predicting the trends in sodium values and that should help in the better management of these patients. How can this study which looks at balance calculations be useful? It is possible to design an application which can predict the serum Na based on volumes of fluids, the sodium content of fluids, urine sodium level, and the projected urine output. Estimates of predicted sodium based on these inputs will be useful to the clinician.

There are a number of pitfalls of this study. The sample size is rather modest. The exchangeable electrolyte balance calculations were based on the average of urine volume estimated which is not entirely accurate. We resorted to this to avoid cumbersome daily 24 h urine Na estimation of all patients in the study group. This does create inaccuracies in the calculation but is a reliable estimate in most patients. It is especially invaluable in the management of hyponatremia.

Conclusion

This study confirms the utility of quantitative analysis in predicting changes in sodium following sellar and suprasellar surgeries

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Conflicts of interest

There are no conflicts of interest.

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