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Two cases of hyperkalemia after administration of hypertonic mannitol during craniotomy

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Abstract
Mannitol is used commonly as an osmotic diuretic to reduce intracranial pressure during the perioperative period of craniotomy. The rapid administration of mannitol solution can cause an imbalance of electrolytes such as sodium and potassium. Here, we report two cases of mannitol-induced hyperkalemia. We demonstrate that administration of mannitol during craniotomy increases potassium iron concentration, and in some cases it may cause disturbance of cardiac function.

Key words Mannitol · Diuretic · Craniotomy · Hyperkalemia

Introduction

Mannitol is used commonly as an osmotic diuretic to reduce intracranial pressure during the perioperative period of craniotomy [1–3]. The rapid infusion of mannitol solution causes an imbalance of electrolytes such as sodium and potassium [2,4]. Here, we report two cases of mannitol-induced hyperkalemia.

Case report

Case 1

A 34-year-old, 174-cm, 62-kg man with subarachnoid hemorrhage was admitted to our hospital for neck clipping of an anterior communicating artery aneurysm. The patient had been in good health and had been administered no medication until the evening of admission, when he presented with a severe headache followed by loss of consciousness. Preoperative 12-lead electrocardiography (ECG), chest radiography, and routine laboratory evaluations showed no abnormalities.

On the same day, the patient was transferred to the operating theater. ECG showed a normal sinus rhythm at a rate of 55 beats/min, normal QRS duration, and a normal QT interval. Lactated Ringer's solution with a $[K^+]$ of 4 mEq was infused. General anesthesia was induced with use of midazolam and fentanyl. After tracheal intubation, muscle relaxation was induced with use of vecuronium, and then the patient underwent mechanical ventilation with minute ventilation volume of 6.5 L/min to achieve an end-tidal carbon dioxide value of 30–35 mmHg. Anesthesia was maintained with use of sevoflurane and 60% nitrous oxide in oxygen. Vecuronium was continually infused to achieve sufficient muscle relaxation. Fentanyl was added as needed. A catheter was then inserted into a radial artery and an arterial blood sample was analyzed with a analyzer (ABC700 model; Radiometer Medical, Copenhagen, Denmark) (Table 1, G1).

The patient was hemodynamically stable throughout induction and at the start of surgery. Mannitol, 20% solution in 300 ml, was administered intravenously for 20 min after craniotomy. Approximately 30 min after the beginning of mannitol infusion (10 min after completion of infusion), the electrocardiograph showed peaked T waves without any arrhythmia and P wave and QRS changes (data not shown). Arterial blood gas (ABG) analysis showed $[K^+]$ of 5.3 mEq (G2). After 10 min, analysis of a blood sample obtained with direct puncture of a dorsalis pedis artery showed $[K^+]$ of 5.4 mEq. Normal saline infusion was started and lactated Ringer's was discontinued. Ventilation volume was increased to 7.5 L/min and 425 mg calcium gluconate was infused to prevent arrhythmia. Infusion of 250 ml 5% glucose in water containing 10 U insulin was also started. ABG analysis after 30 min showed $[K^+]$ of 4.6 mEq (G3). One hour later, immediately after glucose-insulin therapy, ABG analysis indicated $[K^+]$ of

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3.6 mEq (G4). The height of the T wave was normalized. During this time, no pathological ECG changes were observed. Surgery was completed without further incident. At the end of surgery, $[K^+]$ was 3.5 mEq.

Case 2

A 68-year-old, 168-cm, 78-kg man with intracerebral hemorrhage was admitted to our hospital for removal of an intracerebral hematoma. The patient had suffered from hypertension and had been administered a Ca^{2+} antagonist until the evening of admission, when he presented with a severe headache followed by loss of consciousness. Preoperative 12-lead ECG, chest radiography, and routine laboratory evaluations showed no abnormalities.

On the same day, the patient was transferred into the operating theater. At the time of arrival, his ECG showed normal sinus rhythm at a rate of 60 beats/min, a normal QRS duration, and a normal QT interval (Fig. 1A). Lactated Ringer's solution was infused. General anesthesia was induced with use of thiopental, fentanyl, and vecuronium. After tracheal intubation the patient underwent ventilation with minute ventilation volume of 7.0 L/min to achieve an end-tidal carbon dioxide value of 30–35 mmHg. Anesthesia was maintained with use of sevoflurane and 55% nitrous oxide in oxygen. Vecuronium was continuously infused to achieve sufficient muscle relaxation. Fentanyl was used as needed. A catheter was then inserted into a radial artery, and arterial blood analysis was performed at 15 min after start of mechanical ventilation (Table 2; G1).

The patient was hemodynamically so unstable at the time of induction of anesthetics and the start of surgery that nicardipin was used in an on–off manner. Mannitol, 20% solution 500 ml and 4 mg furosemide were administered intravenously during 45 min after craniotomy. Approximately 20 min after the beginning of mannitol infusion, ABG analysis showed $[K^+]$ of 4.1 mEq (G2). At the end of mannitol infusion, $[K^+]$ was 4.9 mEq (G3). At 45 min after finish of mannitol infusion, ECG showed peaked T waves without any arrhythmias and P wave and QRS changes (Fig. 1B). ABG showed $[K^+]$ of 5.4 mEq (G4). At 60 min after the completion of mannitol infusion, bigeminy was observed. $[K^+]$ was 6.1 mEq (G5) (Fig. 1C). Lidocaine, 60 mg, was given intra-

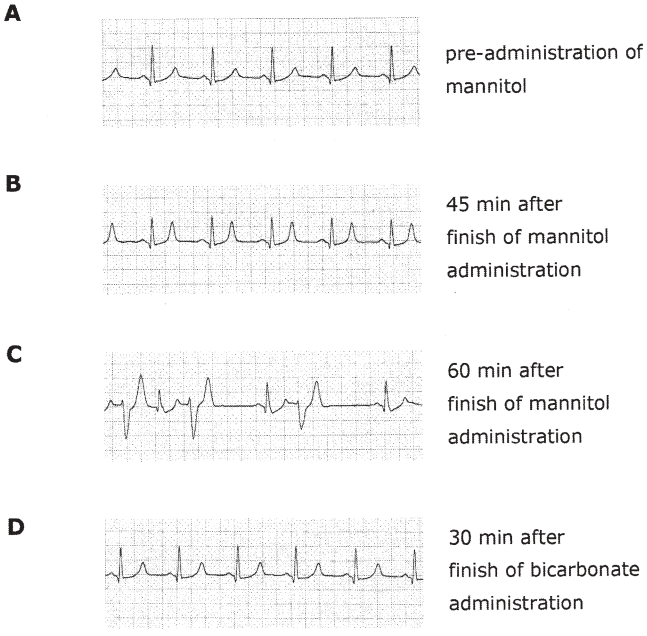

Fig. 1A–D. Electrocardiography of the patient in case 2 around time of mannitol infusion

Table 1. Results of arterial blood gas (ABG) analysis of case 1

	G1	G2	G3	G4
pH	7.36	7.39	7.449	7.429
Pa_{CO_2}	41.8	36.0	31.8	33.1
Pa_{O_2}	261	258	263	256
HCO_3^-	23.0	22.5	23.5	23.0
BE	−1.7	−2.3	−1.1	−1.7
$[Na^+]$	139	141	133	138
$[K^+]$	3.1	5.3	4.6	3.6
Anion gap	12.9	13.9	13.6	11.3

Table 2. Results of ABG analysis of case 2

	G1	G2	G3	G4	G5	G6	G7
pH	7.31	7.29	7.26	7.32	7.34	7.35	7.37
Pa_{CO_2}	42.0	36.7	37.3	32.5	31.8	30.8	32.1
Pa_{O_2}	204	111	94	83	103	135	147
HCO_3^-	19.9	18.1	16.9	18.0	18.6	18.5	20.0
BE	−5.6	−7.8	−9.5	−8	−7.3	−7.4	−5.4
$[Na^+]$	139	133	128	130	130	131	134
$[K^+]$	4.1	4.1	4.9	5.4	6.1	5.9	5.4
Anion gap	12.5	13.6	16.4	17.6	16.4	17.4	16.3

venously to the patient and the bigeminy subsided after 3 min duration. Then 40 ml 7% HCO_3^- solution was infused and the ventilation volume was increased to 9.0 L/min. After 30 min, ABG showed $[K^+]$ of 5.9 mEq (G6). The height of the T wave normalized (Fig. 1D). Surgery was completed without any further incidents. At the end of surgery, $[K^+]$ was 5.4 mEq (G7).

Discussion

These two cases prompted us to review the anesthesia chart in our hospital to investigate the change of serum $[K^+]$ concentration during and after mannitol infusion. Twenty-seven patients who underwent craniotomy for cerebral aneurysm neck clipping, tumor resection, or AVM resection from June 2003 to December 2003 at the Kitano Hospital were enrolled in this study. Compensated $[K^+]$ ($c[K^+]$) was calculated based on the formula $c[K^+] = [K^+] + 0.6X$ (pH 7.4). There are statistically significant differences between $[K^+]$ of pre- (mean, 3.44) and post- (mean, 3.86) mannitol infusion and $c[K^+]$ of pre- (mean, 3.46) and post- (mean, 3.90) mannitol infusion in both raw ($P = 0.0004$) and corrected ($P = 0.0002$) $[K^+]$ (paired t test).

The etiology of hyperkalemia is classified into three categories: increased intake, decreased urinary excretion, and transcellular redistribution of potassium [3]. Our patients were infused at a maximum of $2\,mEq \cdot Kg^{-1} \cdot h^{-1}$ potassium and underwent no blood transfusion, strongly suggesting no potassium overload. Urine output was maintained at more than $0.5\,ml \cdot Kg^{-1} \cdot h^{-1}$ around mannitol infusion. Taken together, these characteristics of our patient cohort suggest that hyperkalemia may have been caused by potassium movement from cells into the extracellular fluid. There are several factors that facilitate the transcellular movement of potassium [3]: an acute increase of plasma osmolality [5], rhabdomyolysis [6], hemolysis, and acidosis. In our retrospective study, no correlation between $[K^+]$ and pH and Base Excess (BE) was detected (data not shown). In addition, there was no evidence that massive rhabdomyolysis or hemolysis had occurred, suggesting that increase of plasma osmolality was the primary reason for the hyperkalemia in our cases. We could not identify the critical factor(s) that determine if mannitol administration causes cardiac event(s).

In conclusion, we demonstrated two cases of mannitol-induced hyperkalemia. Patients who undergo mannitol administration for craniotomy should be carefully observed for this electrolyte abnormality during the perioperative period. Further studies may be required to purify the predictive factor(s) for hyperkalemia and harmful events.

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References

1. Preston R, Hirsh MM, Oster MJ, Oster HM (1998) University of Miami Division of Clinical Pharmacology therapeutic rounds: drug-induced hyperkalemia. Am J Ther 5:125–132
2. Drummond J, Patel P (2000) Neurosurgical anesthesia. In: Miller R (ed) Anesthesia, 5th edn. Churchill Livingstone, Philadelphia, pp 1895–1933
3. Kaye A, Grogono A (2000) Fluid and electrolyte physiology. In: Miller R (ed) Anesthesia, 5th edn. Churchill Livingstone, Philadelphia, pp 1586–1612
4. Seto A, Murakami M, Fukuyama H, Niijima K, Aoyama K, Takenaka I, Kadoya T (2000) Ventricular tachycardia caused by hyperkalemia after administration of hypertonic mannitol. Anesthesiology 93:1359–1360
5. Manninen P, Lam A, Gelb A, Brown S (1987) The effect of high-dose mannitol on serum and urine electrolytes and osmolality in neurosurgical patients. Can J Anaesth 34:442–446
6. Malinoski D, Slater M, Mullins R (2004) Crush injury and rhabdomyolysis. Crit Care Clin 20:171–192