surement of nitrogen dioxide formation from nitric oxide by chemiluminescence in ventilated children (letter). Lancet 341:969, 1993

36. Nilsson AC, Engberg G, Henneberg S, Danielson K, de Verdier CH: Inverse relationship between age-dependent erythrocyte activity of methaemoglobin reductase and prilocaine-induced methaemoglobinemia during infancy. Br J Anaesth 64:72–76, 1990

37. Goutail-Flaud MF: Thérapeutique hydroélectrolytique et nutritionnelle, Réanimation Chirurgicale Pédiatrique. Edited by Murat I, Camboulives J. Paris, Pradel, 1991, pp 61–108

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Acute Hyperosmolar Coma Complicating Anesthesia for Hydatid Disease Surgery

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HYDATID disease is a zoonotic infection caused by cestodes of the genus *Echinococcus*. The definitive hosts are dogs, wolves, jackals, and coyotes; intermediate hosts are sheep, cattle, and deer. Intermediate hosts and humans enter the disease cycle *via* contact with the feces of an infected canine or other definitive host.[1] In the intermediate host, the ingested *Echinococcus* embryo bores its way through the small bowel mucosa and reaches the liver through the portal circulation. Most of the embryos are trapped in the liver where they form cysts; however, some may pass through the liver and form cysts in other organs, particularly the lungs, and less frequently the brain, kidneys, heart, and bones.[1] The cyst cavity is filled with a highly antigenic fluid and small secondary cysts that develop from the germinal layer. The latter produce multiple protoscolices by asexual budding. In intermediate hosts and humans, protoscolices released from a cyst, as a result of spontaneous rupture or surgical manipulation, can differentiate by vesiculation and form secondary hydatid cysts within the host.[1,2]

Surgical intervention is the primary treatment for hydatid disease. During surgery, the cysts must be handled carefully to prevent spillage of the antigenic fluid and viable protoscolices that can cause anaphylaxis or peritoneal echinococcosis.[3] To minimize these complications during surgical manipulation, the area around the cyst usually is packed with pads saturated with 20% saline or 0.5% silver nitrate.[1] Additionally, the protoscolices can be killed by irrigation of the cyst cavity with hypertonic saline, silver nitrate, formalin, or cetrimide before resection.[1] We present a case of hyperosmolar coma that developed during the surgical removal of a liver hydatid cyst. During surgery, 20% saline solution was used for irrigation and on packing sponges.

Case Report

A 13-yr-old boy (38 kg) was admitted to the hospital with flu-like symptoms and acute pain in the left upper abdomen. Hepatomegaly was noted on palpation. The chest radiogram showed a well-circumscribed infiltrate in the inferior lobe of the right lung, consistent with cyst formation. Ultrasonic scanning of the abdomen revealed a cystic defect in the left lobe of the liver, with internal echoes typical of an *Echinococcus* cyst.[4] Computed tomography confirmed the cystic nature of both defects. The lung cyst was 6 cm in diameter. The liver cyst, 12 cm in diameter, occupied the entire left lobe of the liver. Both cysts had homogeneous contents, a thick capsule, and minimal

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calcifications. Indirect hemagglutination confirmed the diagnosis of hydatid disease. On the 3rd day after the patient's admission, his condition deteriorated acutely; he became febrile (38.8°C) and tachypneic, and his abdominal pain increased. Impending rupture of the cyst was suspected, and the patient was scheduled for an emergency laparotomy. Preoperative laboratory tests yielded the following findings: hematocrit, 35%; hemoglobin concentration, 12.4 mg/dl; platelet count, 335,000/mm^3; serum glucose concentration, 90 mg/dl; sodium concentration, 142 mEq/l; chloride concentration, 101 mEq/l, and potassium concentration, 4.1 mEq/l. The patient's mental status was normal.

General anesthesia was induced with thiopental/succinylcholine and maintained with fentanyl, nitrous oxide/oxygen, and pancuronium. The liver was exposed *via* a subcostal incision. The area was packed with sponges saturated with 20% saline. The contents of the hepatic cyst were aspirated carefully through a small incision in the liver capsule. After the evacuation of the cyst fluid, a 20% NaCl irrigation solution was used to "sterilize" the cyst cavity. Approximately 1 l hypertonic saline was used for both the packing sponges and the irrigation. The surgical procedure was completed by performing an omentoplasty and filling the cystic defect with an omental pedicle.[5]

The anesthetic course of the 3-h procedure was uneventful, with the blood pressure ranging between 120/80 and 140/90 mmHg and heart rate remaining between 90 and 110 beats/min. The estimated blood loss was 200 ml. Intravenous fluids were 500 ml Ringer's lactate, followed by 1,000 ml 5% glucose during the last 2 h of surgery. Muscle relaxation was reversed with atropine and neostigmine, and adequate spontaneous respiration ensued. The patient did not awaken, however, and was unresponsive to painful stimulation. Although the patient's pupils were equal and reactive, there was a marked hyperreflexia. This initially was attributed to either the prolonged anesthetic or an opioid effect (clonus). Naloxone (0.2 mg) was given but had no effect. Fifteen min later, the patient had a grand mal seizure that was controlled with intravenous diazepam (5.0 mg). Mechanical ventilation again was instituted. The electrocardiogram showed a sinus tachycardia of 130 beats/min; the patient's blood pressure was 135/95 mmHg. Several minutes later, a second grand mal seizure occurred, and it also was controlled with 5.0 mg diazepam.

The results of laboratory studies drawn after the first seizure were as follows: arterial oxygen tension, 368 mmHg; arterial oxygen percent saturation, 100%; *p*H 7.14; arterial carbon dioxide tension, 46 mmHg; base deficit, −11 mEq/l; and bicarbonate concentration, 15.8 mEq/l. The metabolic acidosis was treated with 25 ml 8.4% $NaHCO_3$. At this point, we discovered that the urinary bladder catheter had become disconnected under the drapes, resulting in a falsely low measured urine output. After the patient was transferred to the intensive care unit, the remaining laboratory results were available: serum sodium concentration, 163 mEq/l (172 mEq/l, corrected for concomitant hyperglycemia)[6]; chloride concentration, 133 mEq/l; potassium concentration, 3.8 mEq/l; calcium concentration, 10 mg/dl; glucose concentration, 670 mg/dl, and urea concentration, 22 mg/dl. The patient's hemoglobin concentration was 11.8 mg/dl, and his hematocrit was 31%. The calculated serum osmolality[7] was 367 mOsm/kg (normal, 275–295 mOsm/kg). A central venous catheter was placed *via* the internal jugular vein, and the central venous pressure was −3 cm H_2O.

The therapeutic plan focused on rehydration and the reduction of both the serum glucose and sodium concentrations. Treatment over the following 6 h was initiated with 2,500 ml 2.5% glucose solution, followed by 1,000 ml 5% glucose solution with a total of 66 U regular insulin and 60 mEq potassium. After 3 h, the central venous pressure was 5 cm H_2O, and the patient was breathing spontaneously and opening his eyes. After 6 h, he was fully awake, alert, had normal deep tendon reflexes, and clearly was uncomfortable with the endotracheal tube. At that time, laboratory values were as follows: glucose concentration, 133 mg/dl; sodium concentration, 149 mEq/l; chloride concentration, 123 mEq/l, and potassium concentration, 3 mEq/l. The central venous pressure was 8 cm H_2O. The patient's trachea was extubated. On the following day, his neurologic exam and mental status were entirely normal, and he was discharged from the intensive care unit.

Discussion

Human infection with the larval stage of the canine tapeworm, *E. granulosus*, known as hydatid disease, is reported frequently in the Mediterranean littoral region, the Middle East, Australia, New Zealand, and South America.[3] Hydatid disease is rare in the contiguous United States; the first human case reported in the United States was diagnosed in Minnesota in 1977.[8] In the contiguous states, the disease is acquired by 3–5 individuals each year. Hydatid disease acquired outside the country is diagnosed in 100–200 U.S. residents annually.# Interestingly, in Alaska, Eskimos contract the disease at an average annual rate of 28:100,000.[9]

Diagnosis of hydatid disease is based on the clinical picture, epidemiologic information, and radiologic findings, and is confirmed by serologic testing. Diagnostic percutaneous needle aspiration of the hydatid cyst should not be attempted, because spillage of the cyst contents can cause anaphylaxis or secondary spread of the disease.[3,4]

Perioperative complications of hydatid disease can be related to the following conditions: (1) mechanical symptoms due to either the location and size of the cyst (brain, heart, lung, liver) or rupture of the cyst; (2) systemic reactions caused by the antigenic material in the cyst cavity (pruritus, generalized urticaria, or anaphylaxis); (3) secondary infections or sepsis; or (4) complications caused by the protoscolicidal solutions (*e.g.*, hypernatremia or a local reaction such as sclerosing cholangitis).[10]

We have described a case of delayed recovery from anesthesia due to acute hyperosmolar coma caused by combined hypernatremia and hyperglycemia. Although the hyperglycemic response to surgical stress is well

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known, severe perioperative hyperglycemia is unusual in the nondiabetic patient. On the other hand, during surgery, the degree of hyperglycemia is directly proportional to the glucose infusion rate. Schwartz *et al.*[11] showed that glucose administered intraoperatively at a rate of 12.5 g/h consistently resulted in plasma concentrations greater than 200 mg/dl; the glucose infusion in our 38-kg patient during the last 2 h of surgery was approximately 25 g/h. In addition, the severe surgical stress might have contributed to an even greater degree of hyperglycemia.

Hypernatremia causes a relative free-water deficit with a resultant increase in the solute concentrations of all body fluid compartments. Hypernatremia caused by exogenous intake of salt is uncommon but can be fatal.[12] The use of hypertonic (20%) saline during therapeutic abortion rarely results in mortality: one death is reported in every 49,474 cases.[13] Kerenyi,[14] however, described a case in which hypernatremia caused a death after the intrauterine instillation of hypertonic saline. The resultant massive ascites and coma suggested that some of the injected hypertonic saline leaked into the peritoneal cavity. We believe that a similar scenario existed in our case. Although it is standard procedure in our institution to use 20% NaCl (for irrigation and packing sponges) during the surgical treatment of hydatid cysts, we previously have not encountered a hypernatremic complication, possibly because the chitinous-laminated acellular layer of the cyst capsule is nearly impermeable to solutes.[1,4] We believe several mechanisms were responsible for the acute hypernatremia in our case. First, hyperglycemia caused an osmotic diuresis that was not recognized during the operation. Second, irrigation of the cyst with 20% NaCl and the use of the 20% saline-soaked packing sponges resulted in considerable spillage of hypertonic saline into the abdomen. Both osmotic translocation of extracellular water into the peritoneal cavity and inward diffusion of sodium and chloride ions,[15] combined with the hyperglycemic diuresis, were probably the major causes of the hypernatremia and contracted intravascular volume. Finally, the administration of sodium bicarbonate to treat the metabolic acidosis further contributed to the hypernatremia.

Lethargy, the earliest and most common symptom of hypernatremia, can progress to coma and convulsions in severe cases.[16] Tremor, muscular rigidity, and hyperreflexia are also frequent symptoms; however, similar manifestations may occur after narcotic administration.[17] Acute hypernatremia induces an osmotic shift of water from the cells, leading to an abrupt intracellular dehydration. In severe cases, sudden shrinkage of the brain can result in meningeal vessel tears and intracranial hemorrhage.[16,18]

The treatment of acute hypernatremia includes both restoration of normal osmolality and reexpansion of the extracellular volume. The rate of development of hypernatremia and the severity of symptoms guide the speed with which corrective therapy can proceed.[16] In our patient, the coma was rapid in onset ($\approx$ 3 h) and, with aggressive treatment, resolved quickly ($\approx$ 6 h). It recently has been suggested that cases of acute hypernatremia (< 12 h), as in our case, can be treated more vigorously than previously recommended.[16] Aggressive treatment of acute hypernatremia should protect the brain more effectively from the intracellular dehydration and shrinking produced by the acute hyperosmolarity. This is in contrast to cases of chronic hypernatremic hyperosmolarity (> 2 days), in which the rate of correction should not exceed 0.7 $mEq \cdot l^{-1} \cdot h^{-1}$.[16] In either case, careful observation is necessary, and any deterioration in neurologic status should prompt an immediate slowing of therapy and thorough reassessment.

When caring for a patient undergoing hydatid cyst surgery, the anesthesiologist must be prepared to manage several potential problems. During diagnostic needle puncture of an unsuspected hydatid cyst, spillage of the highly antigenic cyst fluid may evoke an anaphylactic reaction.[1] A relative of our patient died suddenly because of anaphylaxis, and the autopsy revealed a ruptured hepatic hydatid cyst. The presence of eosinophilia, pruritus, and a diffuse rash may be signs of "minor leaks" and harbingers of massive cyst rupture.[3] In addition, rupture of a pulmonary hydatid cyst into a bronchus may result in hemoptysis or spillage of infected material into the contralateral lung, causing bronchospasm.[1,2] A double-lumen endotracheal tube should be used to isolate the affected lung from the healthy lung during surgical removal of a lung cyst. If the patient has pulmonary hydatidosis, isolation of the two lungs is necessary regardless of the surgical procedure, because the pressure generated during mechanical ventilation can cause the rupture of a pulmonary cyst. Furthermore, isolating the two lungs with a double-lumen tube probably is indicated in any patient with hydatidosis, regardless of the surgical procedure and regardless of documented pulmonary cysts, because 25% of patients with hepatic cysts will have pulmonary cysts, and patients with cysts elsewhere

(brain, heart, bone, and other points) may have pulmonary cysts.[1,19]

Hydatid cysts in other locations, particularly cysts in the brain and around the heart, may pose special problems for the anesthesiologist. Approximately 3% of patients with hydatid disease develop a cyst in the brain. The presenting symptoms may be increased intracranial pressure or a focal epilepsy.[1] Occasionally, a cyst may form in the pericardium, resulting in a restrictive cardiomyopathy.

In conclusion, a thorough evaluation is necessary before initiating surgery for hydatid disease or any surgical procedure on a patient suspected of having hydatid disease. Depending on the location of the hydatid cyst, various specialized anesthetic principles (thoracic, neurosurgical, cardiac) must be employed during the planning and administration of anesthesia. The possibility of anaphylaxis must be anticipated should rupture of the cyst occur. Electrolyte and acid–base imbalances may occur when hypertonic saline solutions are used as part of the procedure. Electrolyte and acid–base status should be monitored closely if 20% saline is used, and appropriate interventions must be made promptly.

References

1. Schantz PM, Okelo GBA: Echinococcus (Hydatidosis), Tropical and Geographical Medicine. Edited by Warren KS, Mahmoud AAF. New York, McGraw-Hill, 1990, pp 505–518

2. Mahmoud AAF: Diseases due to cestodes, Pulmonary Diseases and Disorders. Edited by Fishman AP. New York, McGraw-Hill, 1988, pp 1726–1729

3. Wolfe MS: The cestodes, Cecil Textbook of Medicine. Edited by Wyngaarden JB, Smith LS. Philadelphia, WB Saunders, 1988, pp 1893–1894

4. Sayek I, Yalin R, Sanac Y: Surgical treatment of hydatid disease of the liver. Arch Surg 115:847–850, 1980

5. Papadinetriou J, Mandrekas A: The surgical treatment of hydatid disease of the liver. Br J Surg 57:431–433, 1970

6. Daugirdas JT, Kronfol NO, Tzamaloukas AH, Ing TS: Hyperosmolar coma: Cellular dehydration and the serum sodium concentration. Ann Intern Med 110:855–857, 1989

7. Rose DB: Clinical Physiology of Acid–Base and Electrolyte Disorders. New York, McGraw-Hill, 1989, pp 589–600

8. Gamble WG, Segal M, Schanz PM, Rausch RL: Alveolar hydatid disease in Minnesota. JAMA 241:904–907, 1979

9. Wilson JF, Rausch RL: A review of clinical features of 33 indigenous cases of *Echinococcus multilocularis* infestation in Alaskan Eskimos. Am J Trop Med Hyg 29:1340–1355, 1980

10. Teres J, Gomez-Moli J, Bruguera M: Sclerosing cholangitis after surgical treatment of hepatic echinococcal cysts: Report of 3 cases. Am J Surg 147:694–697, 1984

11. Schwartz SS, Horwitz DL: Use of a glucose controlled insulin infusion system (artificial beta cell) to control diabetes during surgery. Diabetologia 16:157–164, 1979

12. Moder KG, Hurley DL: Fatal hypernatremia from exogenous salt intake: Report of a case and review of the literature. Mayo Clin Proc 65:1587–1594, 1990

13. Schiffer MA, Pakter J, Clahr J: Mortality associated with hypertonic saline abortion. Obstet Gynecol 42:520–527, 1973

14. Kerenyi TD: Hypernatremia following intrauterine instillation of hypertonic saline solution. Obstet Gynecol 42:759–764, 1969

15. Miller NL, Finberg L: Peritoneal dialysis for salt poisoning. N Engl J Med 263:1347–1350, 1960

16. Oh MS, Carroll HJ: Disorders of sodium metabolism: Hypernatremia and hyponatremia. Crit Care Med 20:94–103, 1992

17. Sprung J, Schedewie HK: Apparent focal motor seizure with a Jacksonian march induced by fentanyl: A case report and review of the literature. J Clin Anesth 4:139–143, 1992

18. Finberg L, Kiley J, Luttrell CN: Mass accidental salt poisoning in infancy. JAMA 184:121–124, 1963

19. Little JM: Hydatid disease at Royal Alfred Hospital, 1964 to 1974. Med J Aust 1:903–908, 1976