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Hydrogen Peroxide Irrigation-Induced Gas Embolism Leading to Cardiac Arrest During Surgery for Brucellosis Spondylitis: A Case Report

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Case Report

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Abstract

Hydrogen peroxide has both antibacterial and hemostatic effects, but it can cause fatal venous gas embolism (VAE), with a higher risk in patients with brucellar spondylitis accompanied by bone destruction. This article reports a case of such a patient who suddenly experienced cardiac arrest after intraoperative irrigation with 3% hydrogen peroxide, suggesting that clinical management during the perioperative period needs to be strengthened and the occurrence of VAE should be vigilantly guarded against.

Background

Intraoperative debridement and disinfection are essential for reducing postoperative infection in spinal surgery.Given its strong oxidative bactericidal activity and hemostatic property, hydrogen peroxide is widely used for irrigation in infective spinal procedures, particularly for debriding infectious lesions and inflammatory granulation tissue[1]. However,it may induce venous air embolism(VAE), a rare but fatal complication during irrigation, and clinical awareness of this complication risk in spinal surgery still needs to be further strengthened[2–4].

Case presentation

A 65-year-old male patient, due to lumbar spinal stenosis, lumbar spondylolisthesis combined with brucellosis-induced spinal arthritis, underwent lumbar lesion resection and intervertebral fusion surgery under general anesthesia.The preoperative electrocardiogram indicated sinus arrhythmia, and the American Society of Anesthesiologists (ASA) classification was grade II; laboratory tests such as blood routine, liver and kidney function, and coagulation function showed no significant abnormalities. After routine anesthesia induction, tracheal intubation was performed, and a combined intravenous-inhalation anesthesia method was used to maintain sedation and analgesia during the surgery. The drugs used included propofol, sufentanil, rocuronium, remifentanil, and sevoflurane. The intraoperative ventilator parameters were: tidal volume 8-10ml/kg, respiratory rate 12-16times/minute, inspiratory-to-expiratory ratio 1:2, PEEP: 5 cmH_2O, and FiO_2: 50%. The patient was admitted to the room at 17:30 and the surgery began at 18:10. At 19:30, after thorough debridement, 15ml of 3% hydrogen peroxide solution was used to rinse the surgical area. The monitor immediately issued an alarm for supraventricular tachycardia, which then rapidly developed into ventricular tachycardia. The blood pressure dropped sharply from the baseline value of 110/60 mmHg to 39/18 mmHg, pulse oxygen saturation (SpO_2) dropped from 100% to 80%, end-tidal carbon dioxide pressure ($EtCO_2$) dropped from 33 mmHg to 17 mmHg, and then ventricular fibrillation occurred, ultimately leading to cardiac arrest. At 19:33, emergency measures were immediately taken: the surgical area was covered with sterile dressings, the patient was quickly turned to the supine position and chest compressions were performed, while synchronized biphasic wave 200 mA defibrillation and intravenous injection of 1 mg epinephrine were carried out. At 19:40, transesophageal echocardiography (TEE) showed that a large amount of gas filled the ventricles, mainly in the left ventricle (Figure 1). At 19:45, an attempt to aspirate the gas embolism through the central venous

catheter failed. After 3 defibrillation shocks, intravenous injection of epinephrine (total dose 5 mg) was given and fluid resuscitation was performed within 30 minutes, and the blood gas analysis at 20:00 showed: PH: 7.25, PCO_2: 59.3 mmHg, PO_2: 116 mmHg, k^+: 3.7 mmol/L, Lac: 8.0 mmol/L, Hb: 12.0g/L. At 20:01, 250 ml of sodium bicarbonate was given by intravenous drip. At 20:15, the patient regained spontaneous circulation, with a heart rate of approximately 120 beats/minute, blood pressure rising to 120/50 mmHg, and SpO_2maintained above 95%. Physical examination revealed unequal pupil sizes (5 mm in the right eye, 4 mm in the left eye), and sluggish light reflex. After assessment by the surgeon, it was determined that the debridement of the lesion site was largely completed, and the surgery was decided to be ended. The wound was sutured in the right lateral position, and the patient finished the surgery at 21:05 and was transferred to the intensive care unit (ICU) for further treatment. After admission to the ICU, an urgent blood gas analysis showed: PH: 7.31, PCO_2: 36.9 mmHg, PO_2: 60.1 mmHg, k^+: 2.7 mmol/L, Lac: 4.4 mmol/L, Hb: 10.2g/L. Symptomatic supportive treatment was received, with invasive ventilation assistance, mode AC/VC, oxygen concentration 100%, dexamethasone for anti-inflammatory, vitamin B6, potassium chloride, and mannitol for potassium supplementation, fluid supplementation, and dipyridamole sodium chloride 25 mg, nutrition for the brain nerve, edaravone right caferol injection solution 15 ml, 0.9% sodium chloride injection 100 ml, intravenous infusion, measures for oxygen free radical clearance for brain protection were implemented. On the 4th day after the surgery, the patient's pupils returned to being of equal size and circular (with a diameter of approximately 3.0millimeters), the patient was conscious, the electroencephalogram was generally normal, the ventilator was successfully removed and the tube was withdrawn, and the patient was able to cough independently. The muscle strength of the limbs is basically normal and there is no edema. The cranial magnetic resonance imaging (MRI) shows abnormal signals in the right occipital lobe, which is considered to be a recent cerebral infarction lesion. On the 7th day after the surgery, the patient was conscious, answering questions clearly and coherently, the pupils were of uniform size and round (with a diameter of approximately 3.0 millimeters), the light reflex was normal, and the vital signs were stable. Subsequently, the patient was transferred to the general ward for further treatment.

Discussion

This study reports a case of fatal venous gas embolism followed by cardiac arrest in a patient with brucellar spondylitis after irrigation with low-volume 3% hydrogen peroxide during lumbar surgery. Despite successful resuscitation with restored spontaneous circulation, the patient developed cerebral infarction. Based on current clinical evidence, we discuss the high-risk factors and perioperative management strategies for this complication.

I. Pathophysiological Mechanism of Venous Air Embolism Caused by Hydrogen Peroxide

Hydrogen peroxide exerts disinfection via strong oxidation and rapidly decomposes into oxygen under catalase action upon tissue contact. This property underlies its debridement effect while predisposing

patients to gas embolism. Even if only 10-20mL is used during the operation, the rapid accumulation of a large amount of oxygen in a short time within the closed or semi-closed bone cavity formed by spinal surgery can lead to a sharp increase in local pressure[5, 6]. High-pressure oxygen enters the circulation via open damaged venous sinuses intraoperatively, obstructing the right ventricular outflow tract and triggering an air-lock effect that causes circulatory collapse and cardiac arrest, consistent with the clinical course of the present case[7, 8]. It is worth noting that transesophageal echocardiography (TEE) in this case showed significant gas accumulation in the left ventricle, which is speculated to be related to the possibly undiagnosed patent foramen ovale (PFO) in the patient—when the right heart pressure increases, PFO can cause right-to-left shunting, leading to venous gas emboli directly entering the systemic circulation and causing paradoxical arterial gas embolism[9]. In addition, the oxygen free radicals produced during the metabolism of hydrogen peroxide can aggravate tissue ischemia and hypoxia damage. This is also one of the important pathological mechanisms for the sequelae of cerebral infarction in this case[8, 10].

II. Special Risks of Hydrogen Peroxide-Related Gas Embolism in Spinal Surgery

1. Anatomical Structure Risk: The spine-surrounding venous plexus features thin-walled, valveless vessels, which are easily disrupted during debridement and internal fixation, leading to open venous sinuses. Bone destruction and local inflammation in brucellar spondylitis further compromise venous wall integrity, creating an anatomical predisposition to gas embolism. At the same time, the bone cavity formed by spinal surgery is a typical semi-closed space. This is also the key reason why the incidence of this complication in spinal surgery is higher than that in surgeries of other parts[5, 6, 10, 11].

2. Misunderstanding of Risk Related to Surgical Position: The traditional view holds that high-risk surgeries involving venous air embolism are mostly performed at locations above the heart, which leads to insufficient vigilance of surgeons against the risk of prone-position spinal surgery[12, 13]. However, recent researchs have clearly confirmed that the prone position cannot eliminate this risk. Although the prone position may slightly increase the central venous pressure, the local oxygen pressure generated by the decomposition of hydrogen peroxide during the operation is often significantly higher than the central venous pressure, and gas can still enter the blood circulation smoothly[14]. This finding suggests that as long as there is a condition for hydrogen peroxide to contact open venous sinuses in a relatively closed space, there is a significant safety risk regardless of the surgical position.

III. Key Factors Affecting the Severity of Complications

Individual differences in patients are important variables affecting the severity and prognosis of gas embolism. Patients with patent foramen ovale (PFO) have a significantly increased risk of paradoxical embolism, and the embolism sites are mostly involved in important organs, with a worse prognosis[9]. In addition, elderly patients have a lower tolerance for gas embolism. Moreover, brucellosis, as a chronic infectious disease, keeps patients in a state of chronic depletion for a long time, thereby further increasing the risk of gas embolism formation and migration[7, 15].

IV. Recommendations for Perioperative Prevention.

Control and Emergency Treatment Based on the experience of this case and recommendations from the latest clinical guidelines, the following clinical suggestions are proposed: 1. For cases with bone destruction and venous sinus exposure, hydrogen peroxide should be avoided, or used cautiously only after sufficient dilution; 2. Strengthen intraoperative monitoring. A sudden drop in end-tidal carbon dioxide partial pressure ($EtCO_2$) can serve as an early warning indicator for gas embolism. If conditions permit, transesophageal echocardiography (TEE) is recommended to monitor gas in the cardiac cavity in real time; 3.Upon gas embolism onset, hydrogen peroxide irrigation must be discontinued immediately, the surgical field covered with sterile dressings, and the patient rapidly positioned in left lateral Trendelenburg posture to prevent bubble entry into the right ventricular outflow tract. Emergency interventions including high-flow oxygen supplementation, chest compressions and defibrillation should be initiated, with right atrial gas aspiration via central venous catheter performed if necessary.

Declarations

Ethics approval and consent to participate

All procedures performed in these studies involving human participants were in accordance with the ethical standards of the institution and/or national research committee. This study obtained approval from the Ethical Committee of Gansu Provincial Hospital of Traditional Chinese Medicine (NO. 2022-024-01). Informed consent was obtained from all individual participants included in the study.

Consent for publication

Written informed consent was obtained from the patient and spouse who is the next of kin to get this case published in a medical journal.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Code availability

Not applicable

Authors’ contributions

WQC: drafted and revised the manuscript.CL and LJL: data collection. CAW: contributed to the critical revision and language editing of the manuscript. The author(s) read and approved the final manuscript.

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Figures

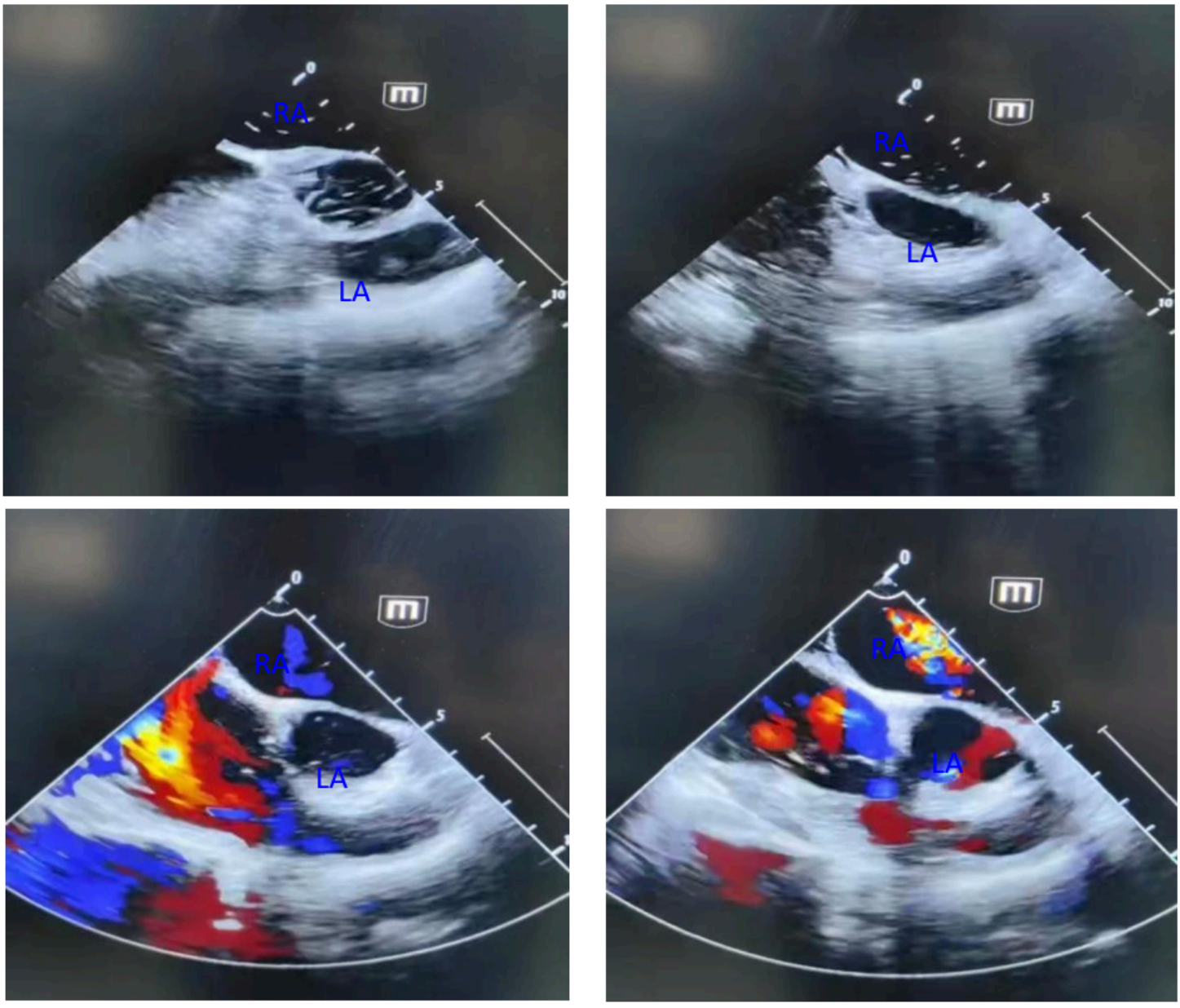


Figure 1

Intraoperative transesophageal echocardiography (TEE) findings, RA:Right atrium, LA:Left atrium.