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Acute Normovolemic Hemodilution in a Patient with Severe Peripheral Arterial Disease: A Rare Case Report

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Abstract: Acute normovolemic hemodilution (ANH) is a blood conservation technique that involves withdrawing blood from a patient before surgery and replacing it with a combination of crystalloid and/or colloid solutions, prior to any surgical bleeding. The withdrawn blood can be re-infused during or after the surgical procedure to reduce the need for allogeneic blood transfusions. Patients with high levels of hemoglobin (Hb) and hematocrit (Hct) are at an increased risk of thromboembolic events due to the higher whole blood viscosity (WBV). By reducing blood cell concentration and blood viscosity, ANH can decrease the thromboembolic events during and after surgery in patients with elevated Hb and Hct levels. This article specifically describes the application of ANH in a patient with critical limb ischemia who underwent lower limb thrombectomy and presented with high Hb and Hct levels. ANH presents a promising new approach to reducing the need for allogeneic blood transfusion, while also potentially decreasing the rate of thromboembolic events perioperatively. However, further research is needed to determine the optimal target Hct for patients with polycythemia undergoing ANH, which will help to establish a goal directed ANH. Additionally, the safety and efficacy of ANH should be evaluated in larger populations to ensure its effectiveness and safety. Despite these limitations, ANH remains a compelling and exciting new approach to minimizing the risk of thromboembolic events during and after surgery, and may represent an important tool for improving patient outcomes in the future.

Keywords: Acute Normovolemic Hemodilution (ANH), Peripheral Arterial Disease (PAD), Critical Limb Ischemia (CLI)

1. Introduction

Acute normovolemic hemodilution (ANH) is a blood conservation method that was first described in the early 1970s during cardiac surgery [1, 2]. The basic idea is to draw out some blood from the patient to lower their hematocrit, and then replace it with a combination of crystalloid and/or colloid solutions before any actual surgical bleeding occurs. This helps minimize the amount of red blood cell loss during the surgical procedure.

According to a scientific statement from the American Heart Association, peripheral artery disease (PAD) refers to atherosclerotic obstruction from the aortoiliac segments to the pedal arteries of the lower extremities [3]. A recent systematic review estimated that PAD affects over 230 million adults globally and is linked to a higher risk of numerous unfavorable clinical consequences [4, 5]. Critical limb ischemia (CLI) is a severe form of PAD in which the blood supply to the affected extremity is severely compromised, resulting in intractable limb pain at rest, non-healing wounds, or tissue loss [6].

PAD is typically characterized by chronically insufficient blood flow, causing inadequate delivery of oxygen to the legs, while CLI emerges as a consequence of chronic blood supply impairment, triggering a chain of pathophysiological events that eventually result in resting pain, tissue damage, or both in the legs [7]. According to a systematic review, patients diagnosed with CLI have reported a 1-year cumulative incidence rate of approximately 20% for mortality and amputation [8]. Isovolumic hemodilution has been reported to increase resting blood flow and pain-free walking distance in patients with PAD [9-12]. In patients with CLI categorized as Rutherford V or VI, repeated therapeutic hemodilution has been reported to improve the tissue oxygen delivery index (TODI), enhance whole blood viscosity (WBV), delay major amputation, and significantly modify endpoints for limb

preservation [13]. Here, we report a case of acute isovolemic hemodilution in a patient with CLI and high levels of hemoglobin (Hb) and hematocrit (Hct) who underwent revascularization surgery.

2. Case Report

A 45-year-old male patient, presented to our hospital with pain in both lower limbs lasting for more than 20 days, which had worsened over the past 6 days. He had initially experienced pain in both lower limbs while walking, without an apparent cause, and did not seek treatment. Six days prior to admission, the pain became so severe that he was unable to walk down. There was no history of abdominal pain, palpitations, nausea, or vomiting. One day before admission, the patient noticed limited mobility in his ankles and knees.

One year prior to admission, the patient underwent interventional thrombolysis for arterial thrombosis in his lower limbs. After the procedure, he received aspirin and clopidogrel treatment but did not follow up regularly. The patient had a history of smoking for 20 years, with a daily intake of 40 cigarettes, and alcohol consumption for 20 years, with a daily intake of 70g. He had not quit smoking or drinking and had always lived in a high-altitude area. He had no other relevant medical history.

On examination, the patient appeared healthy, with moderate build, height of 175cm, and weight of 78 kg. His blood volume was estimated to be around 5500ml (70ml/kg), and his blood pressure was 140/90 mmHg. His pulse was 84/min and regular, and he was conscious and responsive. Systemic examination of the heart, lungs, and central nervous system revealed no abnormalities. However, the skin on both lower legs appeared swollen and red, with no signs of skin rupture or bleeding. Both lower legs and ankles were cold to the touch, and there was severe tenderness. No pulsation could be detected in the dorsalis pedis and posterior tibial arteries of both feet. The patient had limited mobility at the knee and ankle joints in both legs.

The Hb level was 229 g/L, and the Hct was 68%. The prothrombin time (PT) was normal, and the activated partial thromboplastin time (APTT) showed a mild reduction below the normal range. D-dimer was 4. 66 mg/L, fibrin and fibrinogen degradation products were 10.5mg/L, lactate dehydrogenase was 377 IU/L, and hydroxybutyrate dehydrogenase was 253 IU/L. The 3D reconstruction scan of the lower abdomen and limbs (Figure 1) showed extensive stenosis and occlusion of the distal abdominal aorta, bilateral common iliac arteries, and both lower limb arteries.

Considering the patient's condition, thrombectomy of the abdominal aorta, bilateral common and external iliac arteries was performed after adequate preoperative preparation. As the patient's Hb and Hct levels were high, and there was an increased risk of thromboembolic episodes during and after surgery, ANH was performed to prevent possible thrombosis.

After anesthesia induction and trachea intubation, a radial artery catheter was inserted to monitor the patient's blood pressure continuously and perform blood gas analysis. Then ultrasound-guided central venous catheterization was performed and an 8F sheath was inserted to remove blood during ANH. Approximately 1000ml of blood was removed through the sheath, and 1000ml of colloid solution was simultaneously infused through a peripheral venous channel.

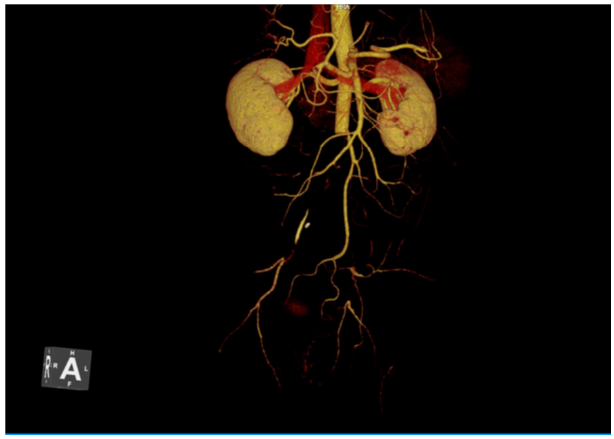

Figure 1. *3D reconstruction scan of the lower abdomen and limbs showed extensive stenosis and occlusion of the distal abdominal aorta, bilateral common iliac arteries, and both lower limb arteries.*

After the procedure, approximately 1000ml of blood was re-infused to combat the loss due to bleeding during surgery. The patient was then transferred to the intensive care unit (ICU) for further treatment and closely monitored. Eight days after the surgery, the patient was discharged and had a subsequent telephone visit without any complaints of abnormalities.

3. Discussion

Patients residing in high altitude areas may develop severe polycythemia, characterized by a Hb concentration exceeds 21 g/dl in men and 19 g/dl in women. This is due to a decrease in arterial oxygen partial pressure, resulting in decreased oxygen saturation of Hb [14]. Increased Hb concentrations lead to elevated whole blood viscosity, resulting in characteristic symptoms such as thrombosis, vascular dysfunction, decreased cerebral blood flow velocity, increased pulmonary blood pressure and heart failure, especially in the right ventricle.

Thrombosis is a significant cause of mortality and morbidity in these patients. Multiple factors contribute to thrombus formation, including increased Hct, thrombocytosis, impaired fibrinolytic activity, and high whole-blood viscosity. An increase in blood viscosity, leading to impaired blood flow, is considered to be the major factor contributing to thrombotic complications that can occur in both arteries and veins, manifesting as conditions such as stroke, myocardial infarction, deep vein thrombosis, or pulmonary embolism.

ANH was initially implemented in cardiac surgery to reduce the need for homologous blood transfusions and

conserve blood resources. Studies have shown that ANH also has positive effects on microcirculation, increasing resting blood flow, and pain-free walking distance in patients with CLI [11]. The decrease in blood cell Hct, red blood cell aggregation, fibrinogen, and plasma viscosity may contribute to these beneficial effects of ANH on microcirculation [15].

To perform ANH, a comprehensive preoperative assessment and preparation is necessary. Firstly, it is essential to take into account the results of preoperative blood gas analysis, coagulation, and inflammatory mediator laboratory tests. Secondly, preoperative echocardiography should be conducted to rule out structural heart disease, pericardial effusion, heart failure, while pulmonary ultrasound should be done to identify and exclude pulmonary edema and other underlying conditions. For patients with severe limb ischemia, assessing the location of thrombosis, related complications, and other concurrent illnesses before surgery is crucial.

In addition, during ANH implementation, It is essential to prepare for invasive arterial catheterization during surgery to enable continuous blood pressure monitoring and blood gas analysis. This will help ensure that the patient's blood pressure remains stable throughout the procedure, and any changes in blood gas composition can be promptly identified and addressed. Central venous catheterization should preferably be performed under ultrasound guidance, as these patients are more prone to develop thrombosis in other venous systems. Prior to the operation, a thorough examination should be conducted to prevent thrombus detachment that may lead to pulmonary embolism. An 8 to 9F sheath should be placed in the central vein to facilitate blood drainage through the large central vein channel during ANH. At least one peripheral intravenous catheter should be set up to administer the replacement fluid. Monitoring of central venous pressure is necessary to guide fluid infusion, and cerebral oxygen monitoring is also essential to reflect cerebral tissue perfusion since these patients may experience decreased cerebral blood flow velocity [16]. Therefore, monitoring cerebral blood flow perfusion is also crucial during ANH.

It's crucial to note that the speed of blood collection during ANH cannot be significantly increased, especially in older patients or those with concurrent cardiovascular conditions who may not tolerate rapid ANH even when maintaining normovolemia. It's also essential to label harvested ANH blood properly and store it at room temperature in close proximity to the patient to prevent erroneous retransfusion and preserve platelet function, which can become compromised if stored in a refrigerator.

Although the target Hct for ANH is flexible, it typically falls within the range of 25% to 30% for patients with a normal Hct. However, for patients with severe polycythemia, the best Hct target is unknown. The relationship between the oxygen carrying capacity of red blood cells and Hct has seldom been studied in these patients, and further study is needed to determine the optimal Hct levels for ANH in patients with severe polycythemia.

4. Conclusion

ANH is a blood conservation method that aims to prevent excessive blood loss during surgery. However, patients with high Hb and Hct are at greater risk of thromboembolic events due to the increased WBV. To prevent perioperative thromboembolic events and reduce the risk of postoperative complications, this article describes the use of ANH in a patient with high Hb and Hct undergoing lower limb thrombectomy.

In this case, ANH can effectively reduce the incidence of thromboembolic events by lowering the concentration of blood cells and reducing blood viscosity. This provides a new approach and treatment method for the management of patients with polycythemia. However, although this case demonstrates the potential benefits of ANH, further research is needed to determine the optimal target Hct and the safety and efficacy of ANH in patients with elevated Hb and Hct levels.

Conflict of Interests

The authors declare that they have no competing interests.

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