Fifth-Time Redo Mitral Valve Replacement via Right Thoracotomy under Systemic Hyperkalemia Cardiopulmonary Bypass without Aortic Cross-clamp

Tomohisa Takeichi, CCP;* Yoshihisa Morimoto, MD;† Akitoshi Yamada, MD;†

Takanori Tanaka, CCP*

Department of *Clinical Engineering and †Cardiovascular Surgery, Kitaharima Medical Center, Hyogo, Japan

Kitaharima Medical Center, Hyogo, Japan.

926-250, Ichiba-cho, Ono-shi, Hyogo, 675-1392, Japan.

Keywords
cardiopulmonary bypass (CPB), systemic hyperkalemia, right thoracotomy, reoperation

Article available at https://jctj.edpsciences.org or https://doi.org/10.1051/jctj/2023040
Keywords
cardiopulmonary bypass (CPB), systemic hyperkalemia, right thoracotomy, reoperation

Abstract
The surgical management of prosthetic valvular endocarditis (PVE) can be challenging. We report a case of a 46-year-old female patient who had a history of four cardiac operations. We chose a mitral valve replacement via right thoracotomy to enable optimal exposure of mitral valve (MV). Because of multi-reoperations, we employed systemic hyperkalemia for cardiac arrest to protect the heart during cardiopulmonary bypass (CPB) without aortic cross-clamping. Here, we present a complex operation that performed management of CPB under hyperkalemia and the patient had a good postoperative recovery.

Introduction
Five times of cardiac reoperations for PVE are a complex operation with significant risk. Due to the difficulty of aortic cross-clamping, MVR is performed under beating
heart (BH) or ventricular fibrillation (VF) conditions. On-pump BH or VF valvular operations may have some technical advantages and utilities (1). However, some studies have shown that BH alternative with VF approach is inferior to the empty heart technique due to its reduction in oxygen delivery to the subendocardium and the consequent suboptimal myocardial protection (2, 3). In this case, we determined that it was difficult to perform MVR via right thoracotomy procedure under BH and VF technique. Because, we had no previous experience with BH technique in complex reoperation cases and, there was a need to secure a surgical field of view close to cardiac arrest. Moreover, though VF condition was not an inappropriate myocardial protection strategy (4), in this case, the prolonged operative time was anticipated. Longer VF time, the more reduction in oxygen delivery to the subendocardium, and the more CK-MB increases (5,6). Therefore, in the case of VF, we thought that weaning from CPB was difficult under the prolonged VF time, and we chose the systemic hyperkalemia strategy during CPB to protect the heart.
This study was approved by the Institutional Review Board at Kitaharima medical center (IRB-0443) with the waiver of informed consent.

Case Report

The patient (height 156 cm; weight 41 kg) had a history of recurrent cardiac operations, starting with a mitral valve replacement (MVR) at the age of 31 for infective endocarditis. At the age of 33, she underwent two further reoperations, including MVR for stuck valve and patch repair for pseudoaneurysm of the ascending aorta due to mediastinitis. Additionally, an omental wrapping was performed. At the age of 42, the patient underwent an emergency MVR via right thoracotomy under VF of the stuck valve.

And this time, the patient was diagnosed with sepsis and prosthetic valve endocarditis (PVE) by transesophageal echocardiography (TEE) and positive blood cultures in our clinical microbiology laboratory. Mitral valve and aortic valve regurgitation were not
confirmed. A five times MVR via right thoracotomy procedure was planned. We performed systemic hyperkalemia for cardiac arrest during CPB without aortic cross-clamping because of computed tomography (CT) scan showed that omental tissue covered from the right atrium to the entire surface of the aorta (Figure 1, 2).

Following induction of general anesthesia, the patient underwent MVR via right thoracotomy procedure. CPB was established with a venous cannula 22/22Fr (MICS Cannulae; LivaNova, Tokyo, Japan) placed in the right femoral vein and an arterial cannula 16Fr (PCKC-A, MERA, Tokyo, Japan) placed in the right femoral artery.

Centrifugal pump (MERA Centrifugal Pump HCF-MP23, SENKO MEDICAL INSTRUMENT, Inc., Tokyo, Japan) was used for CPB, which target pump flow was 2.6 L/min per m². Phenylephrine and noradrenaline were administered to maintain a mean arterial pressure above 70 mmHg. Anticoagulation was given at an initial dose of 300 IU/kg to achieve a goal activated clotting time of at least 480 seconds and if activated clotting time was less than 480 seconds, an additional dose of 4000 IU was given. A CDI Blood Parameter Monitoring System 500 (Terumo, Tokyo, Japan) was recalibrated.
every 30 minutes, and an arterial blood gas sample was also checked every 30 minutes.

The patient was cooled to 28 °C centigrade. To perform myocardial protection due to systemic hyperkalemia, we used 10mL of MgSO₄ and a mixture solution which mixed 500mL of bicarbonate ringer solution with 50mL of KCL 10mEq/L.

When VF occurred at 28.0 degrees, the left atrium opened via right thoracotomy. And we administered an initial dose of 10mL of MgSO₄ and 500mL of mixture solution to achieve cardiac arrest. Immediately following the administration, VF stopped and the duration was 3 minutes. To maintain cardiac arrest, we continuously infused a solution to maintain a blood potassium level of 9mEq/L and administrated 10mL of MgSO₄ every 30 minutes. Because it was not possible to obtain cardiac arrest at a blood potassium concentration of 8.0mEq/L (Figure 3, 4). The body temperature was maintained at 28.0 degrees. After thorough debridement of the extensive vegetation and removal of the artificial valve, redo MVR was performed using Epic 25mm (Abott Medical) valve. When a left ventricular vent through the MV was useful in preventing aortic valve release, we started rewarming the temperature and lowering potassium
levels in the blood by using dilutional ultrafiltration (DUF). Also, we used continuous glucose-insulin therapy. To decrease from 9mEq/L to 5.5mEq/L level of potassium in the blood, we took about 60 minutes. The potassium level after CPB weaning was 5.5mEq/L. The peak potassium level was 9.9mEq/L, the minimum was 8.0mEq/L, and the total potassium administered was 250mEq. Weaning from CPB was performed using catecholamines, primarily dobutamine and from which could easily wean. Cardiac arrest time and CPB time were 180 minutes and 273 minutes, respectively.

The patient’s postoperative maximum creatine-kinase MB (CK-MB) level was 19. The duration of mechanical ventilation and length of stay in the intensive care unit (ICU) was 16 hours and 3 days, respectively. The postoperative course was uneventful and she was discharged after undergoing antibiotic treatment for 6 weeks.

Informed consent to report patient information and image was obtained.

**Discussion**
Reoperative valve surgery is acknowledged to be more complex and increased morbidity and mortality rates (1). The techniques of MV reoperation are becoming important because many patients have received MV repair or bioprosthetic valve replacement over the last few decades, and these patients are prone to revisional operations in the future. The right thoracotomy approach for reoperations enables optimal exposure of the MV. Redo MV procedures can be performed on either the empty BH or in case of VF arrest and systemic hyperkalemia arrest (2, 6). However, some researchers showed that VF approach is inferior to the empty heart technique due to its reduction in oxygen delivery to the sub-endocardium and the subsequent suboptimal myocardial protection (2, 3). The flow to sub-endocardium occurs during diastole. The compressive force exerted on the sub-endocardial muscle by fibrillation restricts the flow and oxygen delivery to the myocardium during the diastolic phase of ventricular fibrillation (7). Imanaka et al showed that the more prolonged VF time, CK-MB increased and the longest VF time was 146min. But such an extended period of VF did not cause severe myocardial damage (5). Also, Hiraoka et al reported that
intraoperative myocardial protection under mild hypothermia and VF was not an inappropriate myocardial protection strategy compared to cardiac arrest with cardioplegic solution (4).

On the other hand, BH approach and systemic hyperkalemia avoid sub-endocardial hypoperfusion mismatches, which are commonly observed with VF. Additionally, during ischemic arrest, myocardial edema increases in the static diastolic state and may lead to cardiac dysfunction (6). In the case of systemic hyperkalemia, provides complete electromechanical diastolic arrest with uniform myocardial protection as opposed to fibrillatory arrest without the fear of cardioplegia washout (8,9). Some studies have suggested that reoperative cardiac surgery can be safely performed with previous CABG and internal thoracic artery (ITA) using systemic hyperkalemia and arrest without the ITA graft (8-10).

In this case, we employed systemic hyperkalemia for the complex reoperation and were able to safely perform myocardial protection. To achieve myocardial protection, we administered an initial dose 10mL of MgSO$_4$ and 500mL of mixture solution and
maintained systemic potassium concentration 9.0mEq/L by continuously infusing a drop and administrated 10mL of MgSO$_4$ every 30 minutes. The peak potassium level was 9.9mEq/L, the minimum was 8.0mEq/L, and the total potassium administered was 250mEq. Weaning from CPB was easy and the maximum level of postoperative CK-MB was 19. Some studies show that cardiac protection due to systemic hyperkalemia without aortic cross-clamp can perform a safe option and protect the heart (8, 11). Moreover, compared to hypothermic cardiac arrest, hyperkalemia cardiac arrest is associated with decreased myocardial adenosine triphosphate level (12). In our series, CK-MB was slightly increased. In terms of becoming 9.9mEq/L of potassium level, we calibrated CDI parameter at 30-minute intervals. However, since the potassium concentration of CDI can only be measured up to 8.0mEq/L, when we checked an arterial blood gas sample every 30 minutes, the peak potassium level was 9.9mEq/L. In this case, as it was not possible to obtain cardiac arrest at a blood potassium concentration of 8.0mEq/L, we maintained a blood potassium level of 9mEq/L.
However, this method of systemic hyperkalemia to achieve cardiac arrest has some drawbacks. First of all, to maintain a mean arterial pressure above 70mmHg, we used phenylephrine and noradrenaline. But other reports suggest that systemic hyperkalemia may reduce vascular tone by affecting potassium channels (13, 14). Next, it may take some time to decrease the systemic potassium concentration. In this case, we used DUF methods and glucose-insulin therapy to return to normal potassium levels. Intracellular potassium is moved to the extracellular compartment during rewarming, suggesting that hyperkalemia is caused by administered potassium as well as by transport from the intracellular compartment and its effective removal is crucially important. In fact, we took about 60 minutes to decrease the potassium level to 5.5mEq/L. To prevent postoperative fatal arrhythmia due to hyperkalemia, the most important procedure is to remove excessive serum potassium during CPB (15). However, it is difficult to decrease high potassium levels in a short time using DUF alone. A study has shown that the use of gravity drainage type hemodiafiltration method is useful for correcting hyperkalemia occurring during extracorporeal circulation because of simple structure (16).
We believe this strategy is useful in complex cases to protect the heart. However, some researches show that CPB under systemic hyperkalemia is safe, few studies have been reported on via right thoracotomy under systemic hyperkalemia CPB without aortic cross-clamping. Therefore, this technique warrants further evaluation.

Conflict of interest

Authors declared no conflict of interest.

Funding

The authors received no funding to complete this research.

Data availability

All available data are incorporated into the article.
The study conformed to the Declaration of Helsinki and was approved by the institution ethics committee in Kitaharima Medical Center, Ono-City, Hyogo Prefecture, Japan. Medical research is subject to ethical standards that promote and ensure respect for all human subjects and protect their health and rights.

Authors’ contributions

T.T. designed the studies. T.T. performed the research and analyzed the data. T.T. provided expertise in clinical data analysis. T.T. wrote the manuscript, and all authors contributed to the final version.
1 References


1 Figure

2 Figure 1
Figure 2
Figure 3
Figure 4
Figure Legends

Figure 1. Preoperative contrast-CT indicates that patch repair for pseudoaneurysm of the ascending aorta. CT.: Computed Tomography.

Figure 2. Preoperative contrast-CT indicates that omental tissue covers from the right atrium to the entire surface of the aorta. CT.: Computed Tomography.

Figure 3. ECG of systemic hyperkalemia during CPB show a blood potassium level of 8mEq/L. ECG: Electrocardiogram; CPB.: Cardiopulmonary bypass.

Figure 4. ECG of systemic hyperkalemia during CPB show a blood potassium level of 9mEq/L. ECG: Electrocardiogram; CPB.: Cardiopulmonary bypass.