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esCCO Case Report Vol. 1

Hemodynamic Management Using Estimated Continuous Cardiac Output (esCCO)

during Kidney Transplantation in a Patient with Hypertrophic Cardiomyopathy

Submitted by:

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Introduction

In pediatric kidney transplantation, it is important to supply sufficient oxygen to prevent ischemic damage to the grafted kidney. Consequently, adequate volume of fluid infusion is required throughout and after the transplant surgery. In patients with hypertrophic cardiomyopathy (HCM), increased cardiac contractility could lead to obstruction of left ventricular outflow, and eventually induce heart failure. In this study, we used estimated continuous cardiac output (esCCO) derived from pulse wave transit time (PWTT) to adequately manage the circulation of a patient with HCM. Also, estimated systemic vascular resistance index (esSVRI) was calculated by using esCCO. Continuous information of the peripheral vascular resistance provided by esSVRI was especially useful.

Preoperative Diagnosis

A 14 year-old male child with a height of 145 cm and a weight of 31 kg was scheduled to undergo secondary transplantation from an ABO-incompatible donor (patient's mother). A chest X-ray revealed CTR 50% and echocardiography confirmed anteroseptal hypertrophy measuring up to 36.6 mm. Thus the patient was diagnosed with hypertrophic cardiomyopathy with left ventricular outflow tract obstruction (**Fig.1**).

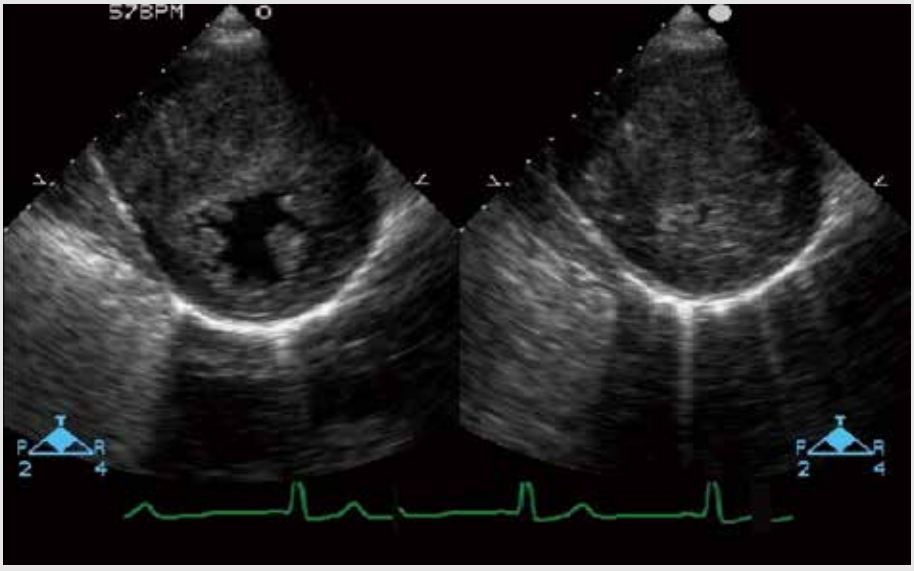

Figure 1.
Preoperative echocardiogram
Asymmetric septal hypertrophy. Significant anteroseptal hypertrophy measured up to 36.6 mm is observed. ROVT observed left ventricle septal flattening. ASH is observed.

Anesthesia Course during Transplantation

Due to the ABO-incompatibility, double filtration plasmapheresis was performed and the antibody level was reduced to 8 before admission to the operating room. Anesthesia was induced with fentanyl, propofol and rocuronium, and maintained with air-oxygen-sevoflurane, rocuronium and remifentanil. In addition to standard monitoring, we used a pulmonary artery catheter (PAC, 5 Fr Swan-Ganz® thermodilution catheter, Edwards Lifesciences, USA), transesophageal echocardiography (TEE), and estimated continuous cardiac output (esCCO, Nihon Kohden Corporation, Japan). The PAC was inserted with echocardiographic guidance via right internal jugular vein. esCCO was calibrated by comparison with intermittent thermodilution cardiac output (ICO).

After starting the surgery, TEE showed an increase of left ventricular outflow gradient (increased blood velocity), which required continuous administration of noradrenaline at a rate of 0.05 μg/kg/min to prevent progression of stenosis (**Fig.2, a**). The esSVRI

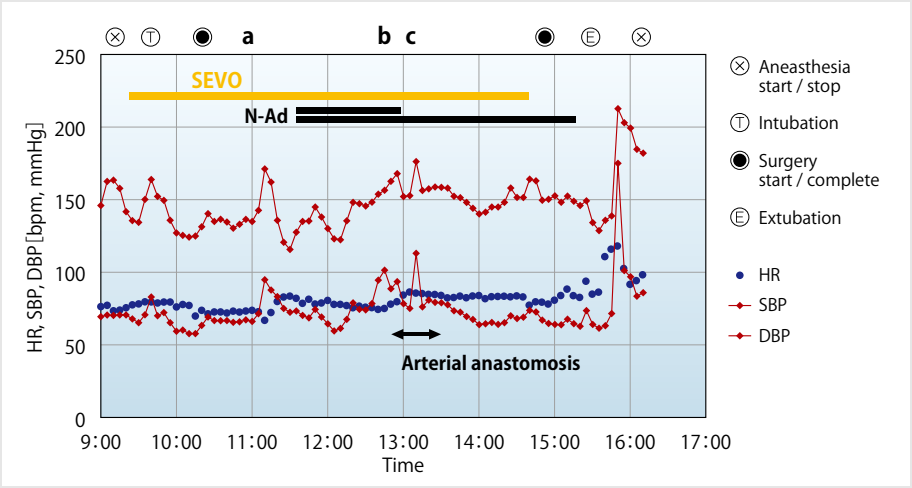

Figure 2.
Anesthesia course

a : TEE observed stenosis
b : TEE confirmed MR
c : observation of first urine
HR : heart rate
SBP : systolic blood pressure
DBP : diastolic blood pressure
SEVO : sevoflurane
N-Ad : noradrenaline

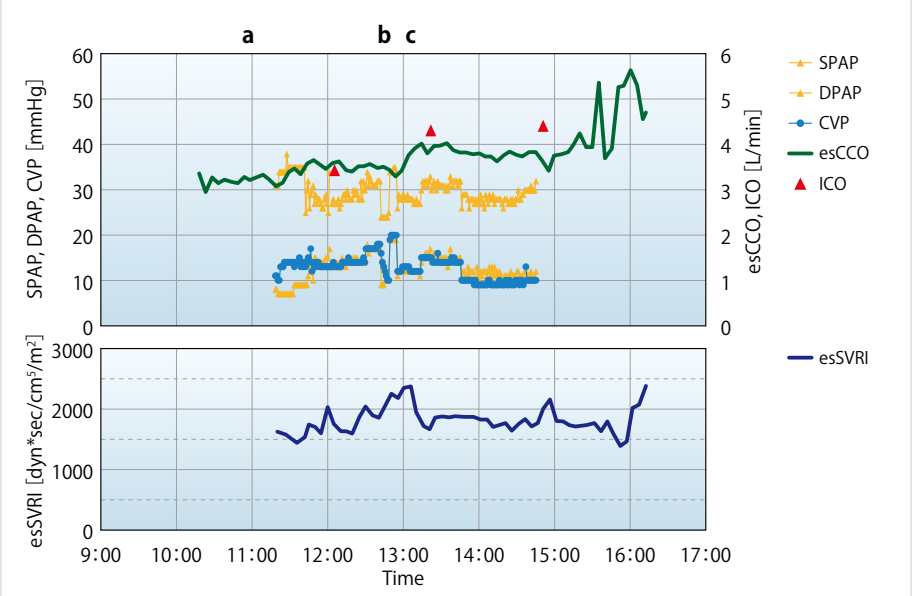

Figure 3.
Change in PAP, CVP, and esCCO

a : TEE observed stenosis
b : TEE confirmed MR
c : observation of first urine
SPAP : systolic pulmonary arterial pressure
DPAP : diastolic pulmonary arterial pressure
CVP : central venous pressure
esCCO : estimated continuous cardiac output
ICO : intermittent thermodilution cardiac output
esSVRI : estimated systemic vascular resistance index

value at the time was 1500 dyn*sec/cm^5/m^2 (**Fig.3, a**). Subsequently as fluid load increased, blood pressure increased. After the start of arterial anastomosis, TEE showed tricuspid regurgitation (**Fig.2, b**). The esSVRI value at the time increased to 2300 dyn*sec/cm^5/m^2 (**Fig.3, b**). Tricuspid regurgitation was resolved upon decreasing the administration rate of noradrenaline to 0.025 μg/kg/min. The esSVRI value at the time decreased to 1900 dyn*sec/cm^5/m^2 (**Fig.3, c**). After that, the value was maintained at between 1500 to 1900 dyn*sec/cm^5/m^2. ICO was measured twice during the surgery in addition to the calibration point and compared to esCCO. The first measurement of esCCO and ICO was 3.95 L and 4.3 L, and the second was 3.66 L and 4.4 L. There was no significant difference between esCCO and ICO. First urine output was observed 8 minutes after reperfusion of the graft (**Fig.2, c**). The surgery was completed with an anesthesia time of 7 hours 36 minutes, blood loss of 690 ml, total infusion volume of 3550 ml, and total blood transfusion of 1280 ml.

Discussion

In a pediatric recipient undergoing kidney transplantation, the child heart has to supply oxygen to the grafted adult kidney. Since oxygen supply depends on cardiac output (CO), it is essential to maintain a relatively higher CO in a pediatric recipient by postoperative fluid loading. In HCM, decrease in preload and afterload and enhanced cardiac contractility may lead to the obstruction of left ventricular outflow, reduction in blood pressure and myocardial ischemia, and consequently result in heart failure[1]. In this study, it was critical to optimize afterload in terms of intraoperative circulatory management. As an index of afterload, we used esSVRI which was calculated by using esCCO and targeted its range between 1500 dyn*sec/cm^5/m^2 where increased left ventricular outflow gradient was observed and 1900 dyn*sec/cm^5/m^2 where tricuspid regurgitation resolved.

Based on the fact that stroke volume (SV) is inversely correlated with PWTT which is the time between ECG R-wave and fingertip pulse wave of a pulse oximeter, SV can be expressed by the following formula[2]:

$$SV = K \times (\alpha \times PWTT + \beta)$$

where α is fixed to -0.3 which is optimally determined for an adult patient[3]. In contrast, K and β is determined by using several vital data obtained at the time of calibration. After calibration, SV is continuously obtained by assigning PWTT sequentially to the above formula. Accordingly, esCCO is calculated by multiplying this SV by the patient's heart rate. Since accuracy of esCCO in a pediatric patient has not been firmly established, we measured ICO intermittently during the procedure to ensure consistency between ICO and esCCO.

In current clinical practice, not every catheter is made for use in a pediatric patient, and the 5Fr Swan-Ganz thermodilution catheter (Edwards Lifesciences) used in this study is not capable of measuring CO continuously. Furthermore, only limited methods are available for measuring CO less or non-invasively in pediatric patients. Bioimpedance method is introduced as a means of measuring cardiac output in pediatric patients and shows superior accuracy to thermodilution in bias and precision[4]. However, it is not recommended for intraoperative use, since the impedance cardiogram electrode should be placed on the anterior chest and it is not suitable for long-term monitoring.

The monitoring of esCCO and esSVRI may be useful as a continuous index for circulatory management. Although a good correlation was shown between esCCO and ICO in adults[5], further study in pediatric patients is still required to fully determine the accuracy of esCCO. When its accuracy is established and precise calibration becomes available, esCCO and esSVRI will be useful in perioperative care monitoring for pediatric patients with heart disease undergoing noncardiac surgery.

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