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/cm²/m² (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/cm²/m²
(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/cm²/m² (Fig. 3, c). After
that, the value was maintained at between 1500
to 1900 dyn*sec/cm²/m². 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. 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/cm²/m²
where increased left ventricular outflow gradient was
observed and 1900 dyn*sec/cm²/m² 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:

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

where $\alpha$ is fixed to -0.3 which is optimally determined
for an adult patient. In contrast, $K$ and $\beta$ 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. 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, 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.
References


