

Anesthesia Management Using Estimated Continuous Cardiac Output (esCCO™) during Kidney Transplantation in a Pediatric Patient - Report of a Suspected Case of Severe Anaphylaxis

Submitted by:

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Introduction

There are several methods for continuously measuring cardiac output (CO) in pediatric patients, such as pulmonary artery catheter, intrathoracic impedance method, transesophageal echocardiogram, and PiCCO (PULSION Medical Systems, Germany). However, all of these methods require invasive procedures. Nihon Kohden Corporation (Tokyo, Japan) has developed a new method called Estimated Continuous Cardiac Output (esCCO™) for measuring cardiac output easily and non-invasively by using only ECG and pulse oximetry signal. This report describes a suspected case of severe anaphylaxis in anesthesia management with esCCO during kidney transplantation surgery.

Case report

A 14 years and 11 months old male child with height of 147 cm and weight of 30.3 kg was referred to us for a kidney transplantation surgery. The patient was an extremely low birth weight infant with gestation period of 31 weeks and birth weight of 788 g. At the age of 2 years and 6 months, he was diagnosed with focal glomerulosclerosis by renal biopsy, with indication of proteinuria. He has been maintained on peritoneal since age 12. He was scheduled to undergo kidney transplantation from a donor (patient's mother).

Preoperative tests showed high levels of blood urea nitrogen (BUN), 33 mg/dl, and serum creatinine (Cr) 12.05 mg/dl, and a low level of hemoglobin (Hgb), 8.4 g/dl. Chest X-ray and electrocardiograph (ECG) showed no sign of other abnormalities. Division of renal artery and vein, common iliac artery and vein was completed. An hour and 20 minutes later after the surgery started, while waiting for arrival of donor kidney, the patient experienced acute reduction of blood pressure and esCCO (**Fig.1, a**), and almost at the same time, the CO₂ waveform (capnogram) disappeared, resulting in a flat line. The patient also had respiratory problems which eventually led to tracheal obstruction. Hemodynamic status remained unstable even after administration of ephedrine and phenylephrine (**Fig.1, b**). In the next 3 minutes, mild flare reaction of chest and face was observed (**Fig.1, c**) so the patient was given 0.2 mg of intravenous adrenaline and 250 mg of methylprednisolone (**Fig.1, d**). A minute later, blood pressure returned to normal range and the normal capnogram appeared. After that hemodynamics stayed stable and respiratory status recovered. The donor kidney was successfully implanted and after the first urine was observed the operation was completed. The patient was extubated in the operating room and then transferred to the ICU.

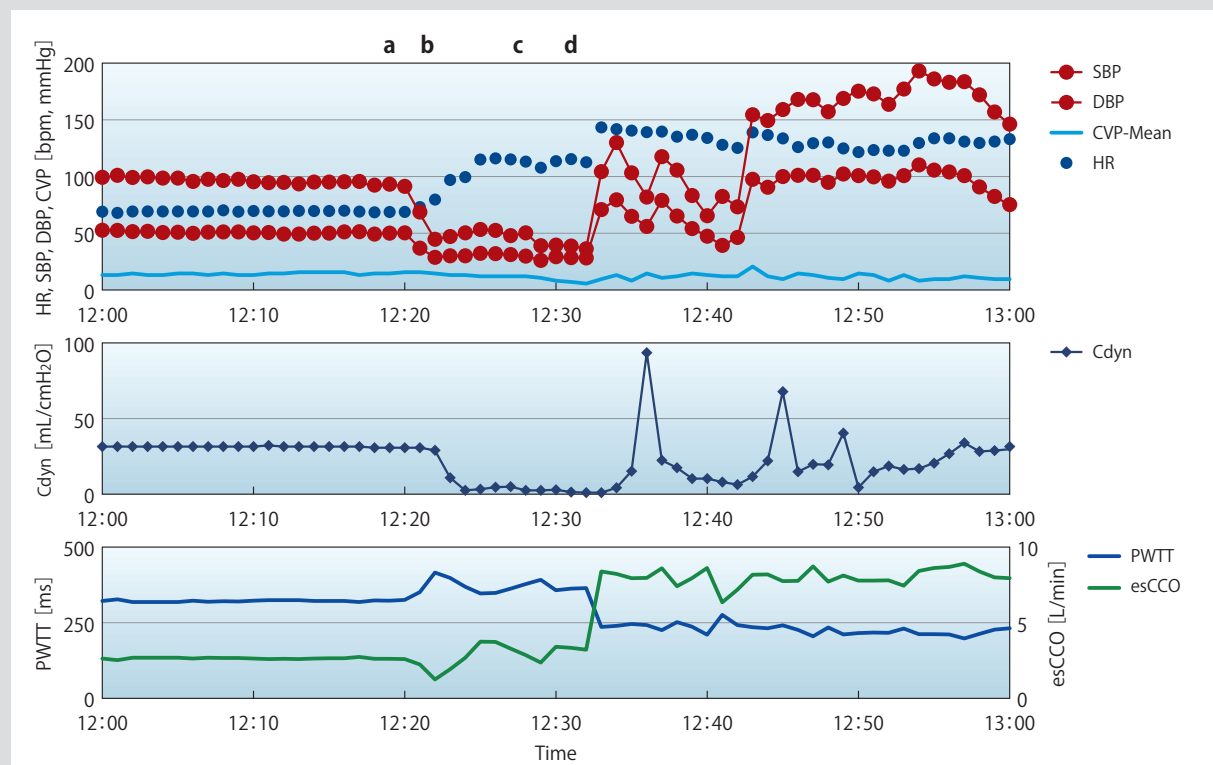


Figure 1. Hemodynamic change during anaphylactic shock

a : Acute reduction of blood pressure and esCCO
b : Administration of ephedrine and phenylephrine
c : Flare reaction seen in chest and face
d : Administration of adrenaline and methylprednisolone

SBP : systolic blood pressure
DBP : diastolic blood pressure
CVP : central venous pressure
HR : heart rate
Cdyn : dynamic lung compliance
PWTT : pulse wave transit time
esCCO : estimated continuous cardiac output

Discussion

Cardiac output measurement in severely ill pediatric patients is considered to improve patient survival rate, although it could involve risk of complications due to its invasiveness¹⁾. With the improvement of technology, less-invasive cardiac output monitoring is becoming available. For cardiac output monitoring, there are two prominent types of methods: continuous and intermittent. Intermittent monitoring methods include thermodilution method using pulmonary artery catheter, and echocardiography²⁾, while continuous monitoring methods include Doppler method with transesophageal echocardiography, PiCCO based on the pulse contour method, and bioimpedance method using ECG. Transesophageal echocardiography, PiCCO and bioimpedance methods are considered to be relatively less-invasive.

Transesophageal echocardiography is less-invasive and uses measurement of aortic valve surface area and TVI (time velocity integral) of blood travel in the aorta. However, it requires highly advanced and expert skills for precise measurement and it might be too complicated for use during surgery. PiCCO is another less-invasive method but requires catheter placement in the brachial or femoral artery. This method is shown to be relatively precise in patients with stable hemodynamics³⁾⁴⁾, while its accuracy in patients with hemodynamic instabilities has not been established⁵⁾⁶⁾⁷⁾. The bioimpedance method requires electrodes placed over the anterior thorax but this is likely to be affected by electrosurgical procedures so this method is restricted to certain surgeries.

In this reported case, we used esCCO (Nihon Kohden, Japan), which is designed to measure cardiac output easily and non-invasively by using

only ECG and pulse oximetry signal. Anaphylactic shock usually accompanies decrease of peripheral vascular resistance and increase of cardiac output. However in this case, the patient experienced shock with sudden decrease of blood pressure and esCCO. Almost at the same time, the patient experienced acute reduction in lung compliance, such as disappearance of the capnogram and ventilatory dysfunction. It appeared most likely that the patient had severe bronchospasm. Air was trapped in the alveoli, intrathoracic pressure increased, blood flow to left ventricular was blocked, and as a result blood pressure and cardiac output suddenly decreased. After that, flare reaction was observed in the anterior chest and face. Blood pressure returned to normal and the normal capnogram reappeared after intravenous administration of adrenaline and methylprednisolone. This showed that the patient had severe bronchospasm followed by anaphylactic shock.

This case indicates that esCCO would be especially helpful to identify sudden changes in clinical status in patients with hemodynamic instabilities.

Brief Summary of esCCO Technology

The esCCO algorithm calculates stroke volume (SV) continuously by using the negative correlation between SV and pulse wave transit time (PWTT) which is determined based on the time from the ECG R-wave peak to the rise point of the pulse oximeter wave. According to the pulse contour method, SV can be expressed as equation (A)⁹:

$$SV = K \times \text{pulse pressure (PP)} \quad (\text{A})$$

At the calibration point, SV is determined by dividing CO obtained from the external device by the heart rate, and PP is determined based on blood pressure (invasive or non-invasive). Then constant K is determined by assigning CO and PP at the calibration point to the equation (A). PP agrees with PWTT in a hemodynamically stable patient and is expressed as equation (B):

$$PP = \alpha \times PWTT + \beta \quad (\text{B})$$

where, α is a fixed value experimentally obtained from past studies^{8,10}. From the relationship between PWTT and PP expressed by equation (B), SV is derived from equation (C), and β is determined by equation (D) below.

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

$$\beta = (SV - K \times \alpha \times PWTT) / K \quad (\text{D})$$

Not only the CO from the external device, CO derived from patient information such as height and weight can also be used for the calibration.

It has been reported that there is a good correlation between esCCO and intermittent thermodilution cardiac output (ICO) in patients without arrhythmia who underwent cardiac surgery⁸. Calibration may be the biggest challenge of esCCO. As mentioned briefly above, esCCO has a patient information calibration (Patient Info Cal) system which allows for completely non-invasive CO measurement. The basis of the Patient Info Cal system is patient information obtained from other clinical studies¹⁰. Multivariate analysis using patient's age, gender, height, body weight as well as blood pressure, heart rate and PWTT at the initial calibration point was performed to obtain CO value for Patient Info Cal. The accuracy of esCCO calibrated with CO obtained by a pulmonary artery catheter has been shown to be clinically applicable⁸. Also, the evaluation of the esCCO performance by Patient Info Cal and that of the accuracy in pediatric patients are ongoing to expand its clinical application. In the near future, we expect that esCCO will be established as a non-invasive and convenient method for perioperative management in pediatric surgeries through the further researches that confirm the performance of esCCO in pediatric patients.

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