Epidural Anesthesia for Cesarean Delivery Facilitated by Minimally Invasive Hemodynamic Monitoring in a Patient With Fontan Repair: A Case Report

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With the advancement of medicine, surgery, and technology, along with the decline in mortality, anesthesia providers encounter patients with complex and rare conditions. One such example is the single ventricle congenital cardiac defect, which is corrected with Fontan reconstructive surgery. To care for patients who have undergone the Fontan procedure, the anesthesia provider needs an in-depth knowledge of the anatomy and physiology behind Fontan circulation. This article presents a brief overview of the anatomy and physiology of Fontan circulation.

The case report describes a parturient who, approximately 2 decades earlier, had undergone a Fontan operation at the age of 4 years and recovered uneventfully. This article discusses the anesthetic management for the patient during cesarean delivery using epidural anesthesia, and the minimally invasive monitoring technology (Vigileo monitor, Edwards Lifesciences) to assist in monitoring the patient intraoperatively.

Keywords: Cesarean delivery, epidural, Fontan repair, Vigileo monitor.

The Fontan repair was first performed by Francis Fontan in 1968.1 The Fontan procedure and its modifications and variants have become the standard treatment for patients presenting with single ventricle heart defects.2 The high survival rates 5 and 10 years after the Fontan procedure (90% and 80%, respectively) provide evidence supporting the effectiveness of this surgery.2 As such, there is an increased likelihood of anesthesia providers encountering this unique patient population.

This case report discusses the use of epidural anesthesia for cesarean delivery in a patient who underwent Fontan surgery at the age of 4 years. Epidural anesthesia has been effective in previous case reports in this patient population undergoing cesarean delivery.3 A unique aspect of this case report is the use of minimally invasive continuous cardiac index monitoring (Vigileo monitor/FloTrac sensor, Edwards Lifesciences) via the arterial blood pressure (BP) catheter.

Case Summary
A 28-year-old woman, gravida 1 and para 0, was admitted to the obstetric unit at 36 weeks of gestation for close cardiac monitoring and management of a high-risk cardiac pregnancy. The patient was born with a double-inlet left ventricle and pulmonary atresia. She underwent multiple surgical operations shortly after birth, including a right-sided Blalock-Taussig shunt, which then led to the Fontan operation at age 4 years. She recovered uneventfully from the Fontan procedure and, according to self-report, maintained an active life with no record of cardiac follow-up over the last decade.

An abdominal ultrasonogram revealed a fetus, with evidence of intrauterine growth retardation (IUGR) in the seventh percentile, in the breech position. The obstetric team stated that the breech presentation might be attributed to a thickened placenta, also discovered during ultrasonography. A cardiology consult advised against a prolonged second stage of labor with extended pushing because of the effect on venous return and increased cardiac workload. Based on these recommendations and the presentation of the fetus, a cesarean delivery occurred as determined by the multidisciplinary team and with the patient’s consent.

On admission to the obstetric unit, intravascular access was established using 2 large-bore catheters, with 0.9% normal saline infusing at a rate of 125 mL/h to establish euvolemia before the scheduled procedure. The patient was monitored by the anesthesia team during admission for fluid optimization in efforts to maximize preload and cardiac output. Intravascular fluid status was assessed using standard signs and symptoms of hypervolemia (periorbital, pulmonary, and leg edema) and hypovolemia (tachycardia, oliguria). Inline intravascular filters were used to decrease the risk of catastrophic air embolism.

Results of the preoperative examination showed no signs of cyanosis or clubbing. Grade 1 edema of the lower extremities was present. Noninvasive BP measurement was 140/90 mm Hg. An electrocardiogram revealed a normal sinus rhythm with a rate of 61/min. Lung sounds
were clear on auscultation and at 93% to 94% oxygen saturation on room air. There was no evidence of aortic valve disease or coarctation. Baseline hematocrit measured 35.6%. An echocardiogram showed the surgically altered anatomy with good left ventricular function and normal flow through the Fontan conduit. No ejection fraction was estimated in the echocardiography report.

On the morning of the scheduled cesarean delivery, the patient was taken from the obstetric unit to the preoperative holding area, where a radial artery cannula was established. An epidural catheter was placed at the L3-4 vertebral interspace using local anesthesia. A FloTrac sensor was then applied to the radial artery catheter and connected to the Vigileo monitor. Initial arterial BP and cardiac index values were 175/82 mm Hg and 5.2 L/min/m². Heart rate measured 72/min in normal sinus rhythm. The patient was transferred to the operating room, and all monitors were reapplied with exaggerated left uterine displacement used. Oxygen was supplied via nasal cannula at 4 L/min. Intravenous administration of 500 mL of albumin and 1,000 mL of lactated Ringer’s solution was given before the epidural test dose. After a negative test dose (3 mL of 1.5% lidocaine with epinephrine 5 μg/mL) through the epidural catheter, slow titrations of epidural boluses were administered. Incremental dosing of the epidural catheter (3-5 mL) of 0.5% bupivacaine with epinephrine, 5 μg/mL, was administered over a 30-minute period, with a total dose of 18 mL. A dermatome level of T4 was achieved, and surgery commenced. Arterial BP and cardiac index measurements at the start of surgery were 168/76 mm Hg and 5.6 L/min/m², and the heart rate was 75/min in normal sinus rhythm.

A viable infant was delivered and immediately taken to the neonatal intensive care unit (NICU) for management of IUGR. The infant was in stable condition, and respirations were self-supported during transfer to the NICU. The mother and father were able to see the infant before the infant’s transfer to the NICU.

The remainder of the surgery was uneventful; the cardiac index increased slightly after delivery to 6.4 L/min/m². The patient received 3 mg of preservative-free epidural morphine after delivery for postoperative analgesia. The estimated blood loss was 750 mL, and the patient received a total of 2,500 mL of intravenous (IV) crystalloid solution and 500 mL of IV colloid solution. Twenty units of oxytocin (Pitocin) were added to lactated Ringer’s solution after delivery to promote uterine contraction.

After completion of the surgical procedure, the patient was transferred to the intensive care unit (ICU) to monitor cardiac status and manage vascular volume. On arrival to the ICU, arterial BP and cardiac index measured 160/82 mm Hg and 6.0 L/min/m², heart rate measured 60/min in normal sinus rhythm, and oxygen saturation read 93% at 4 L/min via NC. After an uncom-

plicated recovery, the patient was discharged from the hospital 4 days after delivery.

Discussion
Fontan reconstructive surgery is performed to improve oxygenation in the cyanotic patient born with certain congenital heart defects. A variety of congenital heart defects are anatomically single ventricle defects. These congenital heart defects are defined by the American Heart Association as hypoplastic left heart syndrome, pulmonary atresia, tricuspid atresia, and single ventricle defects. These defects account for 1% to 2% of all congenital heart defects. Improved oxygenation with the Fontan operation is accomplished by the circulatory alterations that are made during surgery. Fontan circulation is described as passive blood flow to the lungs. Passive blood flow to the lungs is accomplished by creating surgical anastomoses from the systemic venous return to the pulmonary arteries, completely bypassing the right ventricle (Figure). As a result, Fontan circulation is dependent on preload and on the pressure gradient between systemic veins and the left atrium. Anesthesia may alter the unique characteristics of Fontan circulation. Myocardial depression resulting from induction medications and anesthetic gases is compounded in a patient with a single functioning ventricle. Furthermore, increased pulmonary vascular resistance as a result of direct laryngoscopy and intubation may greatly decrease blood flow to the lungs in the patient with Fontan circulation. In addition, positive pressure ventilation may reduce venous return and severely decrease cardiac output in the patient who has undergone the Fontan procedure (“post-Fontan procedure patient”). When possible, spontaneous respirations should be maintained in patients with Fontan circulatory modifications.

Epidural anesthesia has been an effective alternative to general anesthesia in this unique patient population in other case studies. Avoidance of positive pressure ventilation, endotracheal intubation, and myocardial depressant medications provides epidural anesthesia with an appealing advantage over general anesthesia. However, the loss of sympathetic tone due to epidural anesthesia may compromise passive blood flow to the lungs. The reduction of preload, which results from sympathectomy, would produce detrimental effects in the patient with Fontan circulation. This can be combated with adequate fluid management and slow, meticulous titration of epidural anesthesia.

Fluid management in patients who have Fontan circulation is crucial. Fontan physiology poorly tolerates hypovolemia. This is because pulmonary blood flow is reliant on preload and pulmonary vascular resistance. If preload is decreased, pulmonary circulation and cardiac
output may be unfavorably altered. Therefore, avoidance of dehydration by minimizing the nothing by mouth (NPO) period and administering IV fluids for patients with Fontan repair is paramount. Patients with Fontan circulation tolerate higher central venous pressures, with values ranging from 15 to 20 mm Hg. Chronic hypoxia results in polycythemia in post-Fontan procedure patients, resulting in chronically elevated hematocrit and hemoglobin laboratory values. Because of the requirement for increased oxygen-carrying capacity, the threshold for determining when to transfuse blood should be lowered for post-Fontan procedure patients.

Post-Fontan procedure patients are dependent on an adequate atrial contraction to allow for ventricular filling and to maintain an adequate cardiac output in the univentricular heart. Maintaining a normal sinus rhythm can be difficult because of the increased incidence of arrhythmias among this patient population. Arrhythmias are a common occurrence in this patient population as a result of the Fontan surgery and manipulation of the right atrium. Arrhythmias can negatively alter the venous return and cardiac output, thus leading to decreased pulmonary blood flow and decreased filling time of the single functioning ventricle. The patient with Fontan circulation also has very limited preload reserve and contractility; therefore, the cardiac output is dependent on the heart rate.

Monitoring during the perioperative period is crucial in every patient, but may differ slightly in the post-Fontan procedure patient. Because of the altered circulation, it may be necessary to monitor each individual extremity. As a result of the surgically altered circulatory anatomy, with the risks of thrombus/air embolus, infection, and impaired venous return, it is not recommended that central venous lines be placed in these patients unless absolutely necessary. Levels of invasiveness, however, need to be based on the patient's clinical condition and the proposed operative procedure. Furthermore, a low threshold is recommended regarding the placement of invasive arterial BP monitoring.
Along with arterial BP monitoring, cardiac output monitoring, and central venous pressure monitoring are invaluable tools for patients with Fontan circulation. Cardiac output is a key factor of global oxygen delivery. It is often the most manipulated variable when improving oxygen delivery. Because of the manipulated cardiac circulation in Fontan physiology, right atrial pressures are adequate reflections of ventricular function, pulmonary vascular resistance, and pulmonary artery size. However, the risks of central venous access usually outweigh the benefits in patients with Fontan circulation. Besides monitoring cardiac output centrally, continuous cardiac output can be measured in real time through an arterial catheter. This technology is based on an arterial pressure–based cardiac output algorithm. The algorithm is computed by the Vigileo monitor using the FloTrac sensor and is displayed in real time.

Cardiac output (CO) is often expressed in terms of total body surface area (BSA) to compensate for variations in body size. This conversion is known as the cardiac index, or CI: CI = CO/BSA. Normal cardiac index values range from 2.5 to 4.2 L/min/m². By the end of the second trimester, cardiac output in a normal, healthy parturient can increase to a level that is approximately 50% greater than that of a nonpregnant woman. Immediately following delivery, the healthy parturient’s cardiac output can increase by as much as 150% that of pre-pregnancy values.

Along with cardiac output, the Vigileo monitor also displays the cardiac index values. Stroke volume variation can also be tracked using the Vigileo technology. This technology was designed as a tool to guide providers in replacing intravascular volume. However, current literature does not support the treatment of stroke volume variation in the spontaneously breathing patient.

Conclusion
In conclusion, epidural anesthesia and analgesia proved to be an effective form of treatment in a patient with Fontan circulation. The addition of continuous cardiac index monitoring also was an invaluable tool in this case, allowing the anesthesia providers to establish a baseline value. It also provided an extra monitor for early warning signs of hypervolemia, hypovolemia, and cardiac decompensation.

REFERENCES

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At the time this article was written, Tyler Wilhelm, CRNA, was a senior student in the nurse anesthesia program at Oakland University-Beaumont, Royal Oak, Michigan. Tyler is currently working as a staff CRNA at Alle- gan General Hospital, Allegan, Michigan.

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