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CASE REPORTS/CASE SERIES

A transesophageal echocardiography examination clarifies the cause of cardiovascular collapse during scoliosis surgery in a child

Un examen par échocardiographie transœsophagienne précise la cause d'une défaillance cardiovasculaire pendant une chirurgie de scoliose chez un enfant

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Abstract

Purpose *The prone position is required for posterior spinal fusion surgery and may be associated with cardiovascular changes, including a decrease in venous return and cardiac index. We report a case of a patient who developed cardiovascular collapse, increased central venous pressure (CVP), and massive bleeding during posterior spinal fusion surgery. A transesophageal echocardiography examination (TEE) documented a right ventricular outflow tract (RVOT) obstruction associated with the use of transverse bolsters.*

Clinical features *We describe a case of a healthy 14-yr-old male with idiopathic scoliosis who developed severe intraoperative cardiovascular instability and massive bleeding. The surgery was suspended, and the patient was transferred to the intensive care unit.*

The patient subsequently underwent TEE in the supine and prone positions. The echocardiogram appeared normal in the supine position; however, in the prone position with transverse bolsters, we identified a significant decrease in the diameter of the RVOT that worsened with pressure applied against the thoracic spine. The central venous pressure increased from 10-24 mmHg simultaneously. We found appreciably less impact to the RVOT, RV size and flow, and CVP (10 to 14 mmHg) using longitudinal bolsters both with and without pressure to the back. This position was recommended for the patient's reoperation, which was uneventful.

Conclusion *A TEE confirmed a RVOT obstruction in the prone position that was associated, in this case, with the use of transverse bolsters. The RVOT obstruction was explained by the chest deformity, compliant chest cage, bolstering, and pressure applied to the patient's back by the surgeon. This positional RVOT obstruction may explain the increase in the CVP and the secondary massive bleeding during the first operation. The TEE was useful to diagnose the patient's condition and to guide his positioning for the second operation.*

Résumé

Objectif *La position ventrale est nécessaire pour les chirurgies du rachis par voie postérieure; cette position pourrait être associée à des changements cardiovasculaires, notamment une réduction du retour veineux et de l'index cardiaque. Nous rapportons le cas d'un patient qui*

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a manifesté une défaillance cardiovasculaire, une augmentation de la tension veineuse centrale (TVC) et des saignements massifs pendant une chirurgie de spondylodèse par voie postérieure. Un examen par échocardiographie transœsophagienne (ÉTO) a révélé une obstruction de la chambre de chasse du ventricule droit (CCVD) associée à l'utilisation de traversins transversaux.

Éléments cliniques *Nous décrivons le cas d'un adolescent de 14 ans en bonne santé souffrant de scoliose idiopathique qui a manifesté une instabilité cardiovasculaire peropératoire grave et des saignements importants. La chirurgie a été interrompue, et le patient a été transféré à l'unité des soins intensifs. Le patient a par la suite subi un examen d'ÉTO en position de décubitus dorsal puis ventral. L'échocardiogramme a semblé normal en position dorsale; toutefois, lorsque le patient était maintenu en position ventrale à l'aide de traversins transversaux, nous avons observé une importante réduction du diamètre de la CCVD, qui empirait en fonction de la pression appliquée contre la colonne thoracique. La pression veineuse centrale a simultanément augmenté de 10 à 24 mmHg. Nous avons découvert que les traversins longitudinaux, avec ou sans pression dans le dos, avaient un impact considérablement moindre sur la CCVD, la taille et le débit du VD, et la TVC (10 à 14 mmHg). Cette position a été recommandée pour la réopération du patient, laquelle s'est déroulée sans incident.*

Conclusion *Une ÉTO a confirmé une obstruction de la CCVD en position ventrale qui était associée, dans le cas décrit ici, à l'utilisation de traversins transversaux. L'obstruction de la CCVD a été expliquée par la difformité du thorax, la compliance de la cage thoracique, l'utilisation de traversins et la pression exercée sur le dos du patient par le chirurgien. Cette obstruction positionnelle de la CCVD pourrait expliquer l'augmentation de la TVC et les saignements massifs subséquents pendant la première opération. L'ÉTO a été utile pour diagnostiquer la condition du patient et guider son positionnement lors de la deuxième opération.*

Posterior spinal fusion surgery for scoliosis is one of the most complex procedures performed in the pediatric population.[1] The prone position, which is required for the procedure, may be associated with important physiological cardiovascular changes, including decreases in venous return and cardiac index.[2] We report a case of a patient who developed cardiovascular collapse, increased central venous pressure (CVP), and massive bleeding during posterior spinal fusion surgery.

Case description

Parents' informed consent and Institutional Ethics Board approval were obtained to publish this case. A 14-yr-old otherwise healthy male (weight 49 kg, height 172 cm) with idiopathic scoliosis (Cobb's angle 74°) was scheduled for posterior spinal fusion surgery. His cardiovascular history was unremarkable, and there was no history of cardiac murmurs. The patient was not very active physically. On physical examination, there was a marked narrowing of the anteroposterior diameter of his chest and normal heart sounds. His chest wall was not muscular and the heart impulse was easily palpated in the precordial area.

The patient underwent general anesthesia with endotracheal intubation, invasive monitoring (arterial line and central venous catheter) and neurophysiologic monitoring (somatosensory evoked potentials and motor evoked potentials). He was turned to the prone position with transverse bolsters for his chest and individual iliac pads for the pelvis. One hour into surgical dissection and insertion of pedicle screws, the patient developed significant bleeding (approximately 4,000 mL), severe cardiovascular instability manifested by increased CVP from 16 to 20 mmHg, severe hypotension (blood pressure 60 to 70/40 mmHg), and tachycardia (heart rate 130 to 140·min^{-1}) without arrhythmias or ST segment changes. For the next three hours, he was managed with crystalloid fluids (10 L), colloids (6% hydroxyethyl starch 1,250 mL), packed red blood cells (3 U and 600 mL processed cell saver blood), and vasoactive medications (phenylephrine boluses and infusion up to a maximum rate of 1.5 μg·kg^{-1}·min^{-1}, plus epinephrine boluses and infusion at a rate of 0.05 μg·kg^{-1}·min^{-1}). The patient responded initially to treatment, and a dramatic response was noticed when the surgeon was asked to lift the patient's chest from the back. However, the patient became refractory to active treatment (all of the above mentioned plus calcium and bicarbonate), and he developed worsening acidosis (baseline pH 7.38, minimum 7.19, and base excess -11.5). The surgery was aborted and the patient was transferred to the intensive care unit (ICU) for stabilization. He was shifted to the supine position, but his hemodynamic condition was slow to improve. It took several hours in the ICU to stabilize the patient and to wean him off inotropes and mechanical ventilation.

A cardiology consultation was requested to evaluate the patient's cardiac function. A transthoracic echocardiogram showed hyperdynamic biventricular function and normal morphology. Suspecting intraoperative right ventricular compression related to the prone position and the surgical procedure, we performed a transesophageal echocardiography examination (TEE) in the supine, lateral, and prone positions, with and without pressure on the spine. We

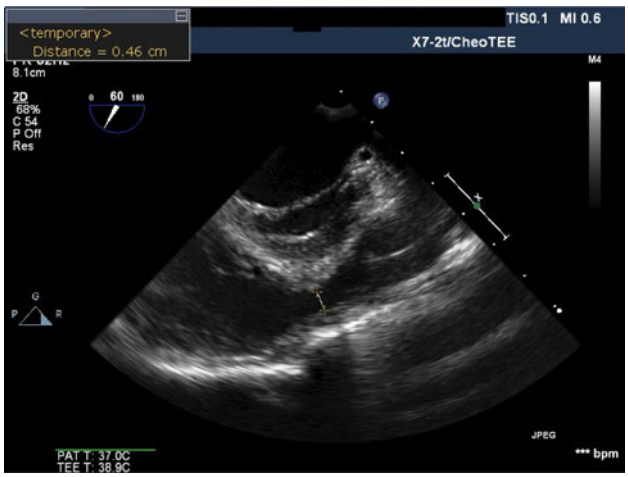

Fig. 1 Supine position. Transesophageal echocardiography mid-esophageal right ventricle inflow-outflow view. Normal anatomy. Symbol (+) showing minimal systolic right ventricular outflow tract diameter 4.6 mm

found a structurally and functionally normal heart in the supine position, without obstruction in the right ventricular outflow tract (RVOT) (Fig. 1 and Video 1). In the lateral position, there was narrowing of the RVOT with flow acceleration.

In the prone position, we used the mid-esophageal RV inflow-outflow view and modified the aortic valve long axis view with the probe turned slightly to the right to study the RVOT. Two-dimensional and colour Doppler images were considered more representative of the changes in position than the absolute pulsed wave Doppler measurements, which were suboptimal because of the perpendicular interrogation angle at the RVOT in the mid-esophageal views. We had technical difficulties obtaining transgastric views. Using transverse bolsters under the patient's chest and pelvis, we identified a significant decrease in the RVOT diameter. With pressure applied to the back by the surgeon, colour Doppler showed a markedly obstructed RVOT (diameter < 1 mm) with a significant decrease in the flow (Fig. 2 and Video 2). No tricuspid regurgitation was identified during this study. We documented simultaneous changes in the CVP from 10 to 24 mmHg.

Using longitudinal bolsters, we found appreciably less impact to the RVOT, RV size and flow, and CVP (10 to 14 mmHg), both with and without pressure to the back (Fig. 3 and Video 3). This position was recommended for the patient's reoperation. Three weeks later, the patient returned to complete his spinal fusion surgery in the prone position. Separate longitudinal supports were used on each side of his chest to avoid pressure on the sternum. Blood loss was 700 mL, and the operation was otherwise uneventful.

Discussion

Recent literature using TEE has documented hemodynamic changes associated with the prone position in patients undergoing scoliosis surgery.[3–5] The most common abnormalities found were decreases in the cardiac index and stroke volume with preserved ejection fraction. These abnormalities are consistent with a decrease in venous return, possibly due to compression of the inferior vena cava.[3,4]

Previous reports have described severe hemodynamic instability associated with using transverse chest supports in the prone position.[5,6] Soliman *et al.*[5] reported two cases with an increase in the CVP and a decrease in the left ventricular diameters in the TEE after the patients were positioned in the Relton-Hall frame. They hypothesized that mechanical compression of the mediastinal structures may cause impaired ventricular filling and an increase in the CVP. Alexianu *et al.*[6] reported a 34-month-old male with neurofibromatosis, scoliosis, and pectus excavatum who developed severe hypotension when placed in the prone position. The TEE documented compression of the RVOT with transverse bolsters, and TEE monitoring proved useful for guiding fluid and for hemodynamic management.[6]

Galas *et al.*,[7] reported another case of a 15-yr-old male with pectus excavatum who developed severe hypotension after being placed in the prone position for elective spinal fusion surgery. Transesophageal echocardiography examination revealed RV inflow compression by the sternum with a mean gradient of 3 to 4 mmHg (peak gradient 7 mmHg) in the supine position. The gradient increased to 9 mmHg (peak gradient 16 mmHg) when external pressure was applied on the sternum to simulate the prone position. Correction of the pectus excavatum was performed prior to uneventful scoliosis surgery.

Denault *et al.*[8] described an alternative method to diagnose RVOT obstruction using a thermodilution Paceport pulmonary artery catheter (Edwards Lifescience, Irvine, CA, USA). They used the pacing port located at 19 cm from the tip to measure RV pressures. Right ventricular to pulmonary artery systolic peak-to-peak gradients > 25 mmHg were considered significant. Significant RVOT obstruction was diagnosed by this method in 4% of patients undergoing different adult cardiac surgeries, and there was good correlation with TEE images and Doppler measurements.

Our TEE examination was limited by technical difficulties in obtaining adequate images and Doppler traces in the prone position. This study's focus was on identifying abnormalities, and time was limited in the interest of patient safety. The RVOT is a three-dimensional structure that moves dynamically throughout the cardiac cycle. We obtained multiple images of the RVOT in the

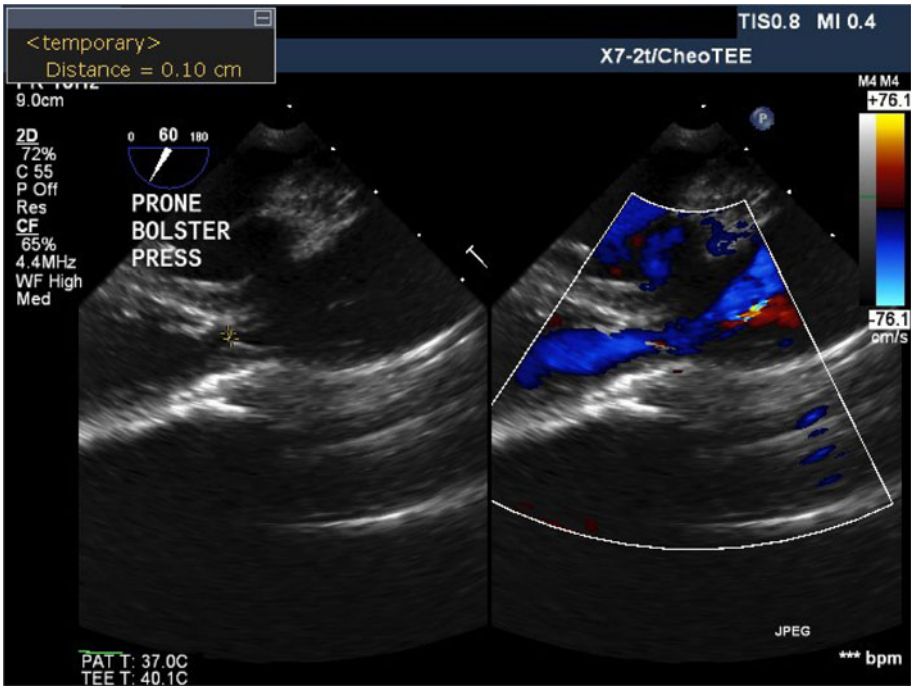

Fig. 2 Patient in prone position with transverse bolsters and pressure in the back. Transesophageal echocardiography midesophageal right ventricle inflow-outflow view to observe the right ventricular outflow tract (RVOT). Marked obstruction of the RVOT with flow acceleration that worsened with pressure in the back by the surgeon. **a** Image on the left. Peak systole. Minimum diameter RVOT 1 mm. **b** Image on the right. Note flow acceleration

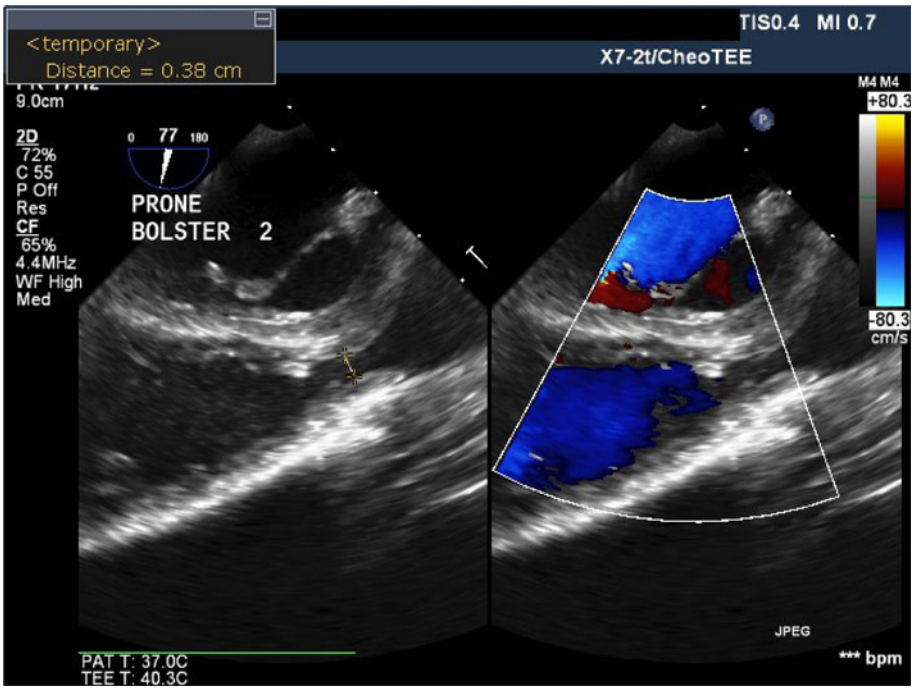

Fig. 3 Prone position with longitudinal bolsters and pressure in the back. Transesophageal echocardiography midesophageal right ventricle inflow-outflow view to observe the right ventricular outflow tract (RVOT). Less obstruction compared with figure. **a** Image on the left. Peak systole. Minimum diameter RVOT 3.8 mm. **b** Image on the right. Note smooth flow

mid-esophageal RV inflow-outflow view as well as in the mid-esophageal aortic valve long axis view that was modified to observe the RVOT. The most satisfactory images were selected to analyze measurements and to suggest the final diagnosis.

Our patient developed severe intraoperative hypotension with elevated CVP refractory to treatment. Transesophageal echocardiography confirmed a RVOT obstruction in the prone position that was associated with the use of transverse bolsters and aggravated by compression on the thoracic spine. These abnormalities were less evident with longitudinal bolsters. External compression in the sternum produced positional obstruction of the RVOT with an increase in the RV afterload, a decrease in the RV compliance, and secondarily, an increase in the CVP. This increase in the CVP may be reflected in the epidural venous plexus, explaining the massive bleeding in the first operation. We cannot eliminate the possibility that a dynamic component

to the RVOT obstruction may be associated with the use of inotropes. Initial RV dysfunction due to RVOT obstruction may produce secondary left ventricular dysfunction and global hemodynamic compromise (interventricular dependence). Tachycardia, hypotension, and elevated filling pressures may decrease coronary perfusion, further worsening cardiac function. All of these factors may explain the late refractory state. The transesophageal echocardiography examination was useful to diagnose the pathophysiologic abnormality and to guide the positioning of the bolster for the patient's second operation.

Conflicts of interest None declared

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