The incidence of vasoplegia in adult patients with right-sided congenital heart defects undergoing cardiac surgery and the correlation with serum vasopressin concentrations

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Background: In adults with right-sided congenital heart disease, vasoplegia during and after cardiopulmonary bypass appears to be a frequent complication. The incidence of vasoplegia in the general adult and pediatric cardiac surgical population has been investigated, but the incidence in adult patients with right-sided congenital heart disease is unknown. Perioperative vasopressin levels during cardiac surgery have been studied in other cardiac surgical patients, but are not known in adults with right-sided congenital heart disease. The purpose of this study was to investigate the incidence of vasoplegia in adult patients undergoing right-sided cardiac surgical procedures requiring cardiopulmonary bypass and to determine the vasopressin response to cardiac surgery in this population.

Methods: Twenty patients were enrolled and demographic, hemodynamic, cardiopulmonary bypass, and use of vasoactive medication data were collected. In addition, perioperative serum vasopressin levels were measured. Sixty adult patients undergoing left-sided cardiac surgery served as controls.

Results: The incidence of vasoplegia in the control patients was 10% and the incidence in the adult patients with right-sided congenital heart disease was 20%. Vasopressin levels were low at baseline (0.5 ± 0.5 pg/mL), increased slightly after induction of anesthesia (0.6 ± 0.6 pg/mL), increased after initiation of cardiopulmonary bypass (99.7 ± 168.2 pg/mL), and decreased after surgery (31.3 ± 43.6 pg/mL).

Conclusions: This study showed that the incidence of vasoplegia (20%) in patients with right-sided congenital heart disease undergoing cardiac surgery was double that of a population of patients undergoing aortic valve surgery (10%). Serum vasopressin concentration was not associated with vasoplegia in this population of congenital cardiac surgical patients. (J Thorac Cardiovasc Surg 2014;148:625-30)

CHD

Vasoplegia has been well described after surgery requiring cardiopulmonary bypass (CPB) as well as during off-pump coronary artery bypass grafting and is defined by hypotension in the setting of low systemic vascular resistance with normal or increased cardiac output.[1] The incidence of vasoplegia in adults undergoing cardiac surgery is between 5% and 25%.[2] Vasoplegia has been associated with increased intensive care unit length of stay and hospital length of stay.[1,3,4] The type of surgery may influence the development of vasoplegia because valve procedures have been shown to have a higher occurrence of vasoplegia compared with coronary artery bypass grafting.[2]

In addition, patients with right-sided congenital heart disease are also at risk for hepatic congestion and subsequent hepatic dysfunction, which may result in a vasodilated hyperdynamic state. Vasoplegia has been investigated in patients undergoing a variety of cardiac surgeries, but patients with right-sided congenital heart disease including tetralogy of Fallot have not been studied previously. Anecdotally, in our practice there appeared to be a higher incidence of vasoplegia in patients with right-sided congenital cardiac valvular disease undergoing repair using CPB as compared with other cardiac surgical procedures.

Low levels of vasopressin may contribute to vasodilatory shock after cardiac surgery.[5] In patients without vasoplegia, vasopressin levels have been shown to increase on bypass, decrease after CPB, and then increase again, and postoperative hypertension is associated with increased levels of vasopressin.[6] In patients undergoing cardiac surgery, an average amount of vasopressor or inotropic support is not known and different practices use a variety of medications for hemodynamic support. The purpose of the current article is to describe the incidence of vasoplegia in adults with right-sided congenital valve disease undergoing

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Abbreviations and Acronyms
ACE-I = angiotensin-converting enzyme inhibitor
ARB = angiotensin II receptor blocker
CPB = cardiopulmonary bypass
CVP = central venous pressure

surgical repair as compared with patients with left-sided valve disease. We hypothesized that the incidence of vasoplegia in this population would be higher than in the general cardiac surgical population and possibly would be associated with an underlying vasopressin deficiency.

METHODS

After institutional review board approval and verbal consent, patients with right-sided congenital heart disease undergoing surgical procedures requiring CPB were enrolled and prospectively evaluated for the occurrence of vasoplegia and levels of vasopressin were measured. These levels were compared with hemodynamics during CPB for potential correlation with hypotension during bypass. Assuming that the true incidence of vasoplegia in the general cardiac surgical population is between 10% and 15%, 20 patients were enrolled. Also after institutional review board approval, a chart review was performed on 60 patients undergoing left-sided cardiac surgical procedures requiring CPB to determine the incidence of vasoplegia in this cardiac surgical population and to establish the dose of vasopressor associated with vasoplegia on CPB.

Inclusion/Exclusion Criteria

Patients older than the age of 18 years presenting for cardiac surgery at the Mayo Clinic (Rochester, Minn) were considered for inclusion. Patients were eligible for inclusion if they had a diagnosis of tetralogy of Fallot, pulmonary atresia, Ebstein's anomaly, or other congenital cardiac disease with primary involvement of the right-sided cardiac valves. Patients undergoing surgeries not requiring CPB were excluded, as were patients with other causes of vasodilatory shock including sepsis. Subjects were recruited in the Cardiovascular Surgery Clinic in cooperation with the cardiovascular surgeons and the Anesthesia Clinical Research Unit.

To evaluate the range of vasopressor use in a similar adult cardiac surgical population, 60 consecutive patients who had undergone left-sided, noncongenital cardiac surgical procedures were reviewed retrospectively to serve as a control group. As the patients with right-sided congenital heart disease underwent pulmonary valve replacement/repairs with some having right ventricular outflow tract repairs performed, adult patients undergoing left-sided cardiac surgical procedures including aortic valve replacement/repair and/or ascending aorta replacement/repairs were included. Patients undergoing coronary artery bypass grafting were excluded because differences in the incidence of vasoplegia have been shown in patients undergoing valvular surgery versus coronary artery bypass grafting.[2] Patients were included if the surgical procedure also included mitral valve replacement or repair, left atrial appendage ligation, or pulmonary vein isolation. Patients requiring hypothermic circulatory arrest, descending aortic repair or replacement, or right-sided cardiac procedures were excluded from this control group.

Cardiopulmonary Bypass Management

The cannulation sites for CPB were at the discretion of the cardiac surgeon and dependent on the surgery. The aorta was cannulated with a patient size-appropriate cannula. Venous cannulation was obtained with either a single 2-stage cannula in the right atrium or separate cannulae in the superior and inferior vena cavae. Anticoagulation was initiated with 400 U/kg of heparin and maintained according to an activated clotting time (iSTAT1; Abbott Labs, Abbott Park, Ill) of more than 500 seconds. Perfusion during CPB used nonpulsatile flow with Sarns 9000 (Terumo Cardiovascular Systems, Ann Arbor, Mich) CPB equipment and a Terumo membrane oxygenator. This equipment uses a hydrophilic interface between the blood and tubing. Smaller circuitry and oxygenators were used for patients with a body surface less than 2.0 m^2. The CPB circuit was primed with 1000 to 1400 mL of Plasmalyte (Baxter Healthcare, Deerfield, Ill), mannitol (50 g), albumin (25 g), and heparin (10,000 U). CPB flows were maintained at 2.4 L/min/m^2. Mean arterial pressure was maintained at 60 to 80 mm Hg during CPB. For patients undergoing aortic cross-clamping, hyperkalemic cold blood cardioplegia was given every 20 to 30 minutes for myocardial protection. Cardioplegia consisted of blood mixed with crystalloid components in a ratio of 4 parts blood to 1 part crystalloid. The crystalloid component consisted of lactated Ringers solution with 50 mEq/L of sodium bicarbonate and either 100 mEq/L (for induction of cardiac arrest) or 50 mEq/L (for maintenance of cardiac arrest) of potassium. Warm, potassium-free restorative cardioplegia was not administered before cross-clamp removal.

Anesthetic Management

Care of these cardiac surgical patients including invasive hemodynamic monitoring and vasoactive medication administration was driven largely by institutional protocols. General anesthesia was induced with propofol or ketamine. Anesthesia was maintained with isoflurane, fentanyl, midazolam, and vecuronium for neuromuscular blockade. Glucose was measured after CPB was commenced and at 30- to 60-minute intervals thereafter. Per institutional protocol, glucose values greater than 180 mg/dL were treated with an insulin infusion. Transfusion administration was guided by a departmental algorithm with defined transfusion triggers. Administration of inotropic agents or vasopressors were recorded in the anesthesia record as per usual practice.

Laboratory Draws

Study patients underwent 5 blood draws that were performed via preexisting intravascular access. The baseline blood samples for study levels were drawn either after placement of an intravenous or arterial line before or immediately after anesthesia induction. The second blood draw was obtained 30 minutes after anesthesia induction or 30 minutes after the baseline blood sample. The third blood draw was performed 30 minutes after the institution of CPB; the fourth blood draw was performed 30 minutes after weaning from bypass; and the fifth blood draw was performed 24 hours after the end of surgery.

Demographic data were obtained including age, sex, height, weight, and sternotomy number. Liver congestion was assessed by recording liver function tests if performed, the presence of ascites, and baseline central venous pressure (CVP).

Outcomes

The primary outcome was the incidence of vasoplegia during CPB (assessed from the need for vasopressors) and the correlation between plasma levels of vasopressin and vasoplegia during CPB. Our practice is not to use pulmonary artery catheters in this population of patients with right-sided congenital cardiac disease, however, per our routine, patients on CPB were maintained with a cardiac index of 2.4 L/min/m^2. This provided a constant cardiac index and vasoplegia could be ascertained from the use of vasopressors to treat patients while on CPB. Phenylephrine was the first vasopressor administered for low mean arterial pressure on CPB, followed by vasopressin if needed. To determine a control vasopressor dose, 60 patients undergoing left-sided cardiac surgical procedures as described earlier were assessed retrospectively for total vasopressor use on CPB and CPB duration. A vasoplegia incidence of 10% to 15% could be expected from previous literature descriptions. The phenylephrine dose in milligrams was added to the vasopressin dose in units and this value was divided by the duration of CPB in minutes (vasopressor/CPB duration ratio). To determine those with vasoplegia, a cut-off ratio was calculated from the