Controlled antegrade single lung reperfusion during double lung transplant

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Abstract
Prompt controlled reperfusion of a pulmonary allograft in a sequential double lung transplant may correct cellular ischemia prior to exposure to full hydrostatic pressures and minimize organ dysfunction. We reviewed the process of a sequential double lung transplant and describe the technique of controlled antegrade graft reperfusion of the initial implant as performed at our institution.

Keywords: Lung allograft; Antegrade perfusion; Lung transplant; In-vivo perfusion

1. Introduction
Organ dysfunction following lung transplantation is a major cause of morbidity and mortality. Both cold and warm ischemia and the subsequent ischemia reperfusion response are important factors in the pathophysiology of this process. The role of early and controlled reperfusion techniques in pulmonary allografts remains ill-defined, but may slow or reverse sub-lethal endothelial and smooth muscle cell injury due to ischemia prior to the return of normotensive, normothermic pulsatile pulmonary artery flow and pressures [1, 2].

Previous to the implementation of this technique, in the setting of cardiopulmonary bypass (CPB) support, early reperfusion of the initial pulmonary allograft (typically the right lung) was accomplished by retarding blood return to the CPB machine, creating a partial CPB circuit. In this technique, the venous line is partially clamped retarding return to the CPB reservoir, partially filling the right heart and promoting pulmonary circulation. Unfortunately, the amount of blood flow being diverted into the pulmonary circulation using this technique is difficult to quantify, and may vary based on the recipient’s venous return volumes, right ventricular function, pulmonary vascular resistance and variably impacts the reliability of pulmonary perfusion. The pulmonary artery pressure may fluctuate resulting in either no antegrade perfusion or too much perfusion with pulmonary artery (PA) pressures >20 mmHg.

Our alternative simple technique described below allows the pulmonary arterial flow to be precisely controlled despite changes in venous return or pulmonary vascular resistance. Furthermore, it guarantees a minimal delivered flow while maintaining a mean PA pressure of <20 mmHg during the initial stages of graft reperfusion.

2. Materials and methods
Following completion of the pulmonary artery and venous anastomoses of the first implanted lung (right, in the figure), a standard cardioplegia delivery catheter (Medtronic DLP 14G aortic root cannula, Medtronic Inc, Minneapolis, MN) is placed at the conus of the main pulmonary artery (Fig. 1) and secured using standard purse-string suture and tourniquet. Warm, oxygenated whole blood (30–37 °C based on system cooling) from the cardioplegia system of the CPB machine (Smart Cardioplegia, Cobe Cardiovascular Inc, Arvada, Colorado) is perfused directly into the main pulmonary artery at flow rates between 100 and 500 cc/min to maintain a mean perfusion pressure of 15–20 mmHg during the subsequent implant of the second donor lung (20–60 min) [3]. This pressure is monitored by the perfusionist who adjusts the flow appropriately.

During controlled antegrade reperfusion, single lung ventilation of the first allograft with a tidal volume of ~250–300 cc (~5–6 cc/kg) with an FiO₂ of 0.21–0.3 l and a positive end-expiratory pressure (PEEP) of 5 mmHg is maintained. After implantation of the second lung, unclamping of the PA and return of blood flow to the second allograft, the flow to the pulmonary artery is stopped. The antegrade catheter is removed from the PA and the cannulation site secured with the previously placed purse-string suture after weaning off CPB is performed according to standard protocol.

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3. Results

We evaluated our double lung transplant data since our institution started doing this procedure one year ago (n = 20, unpublished data). The incidence of clinically significant reperfusion injury in double lung transplants is 15–30% [4]. In our series we observed a drop in the sequelae of reperfusion injury by almost two-thirds. We noted less oxygen requirement (median PaO2/FIO2 ratios 24–72 h after double lung transplant improved), improved chest X-ray appearances of pulmonary edema within 72 h following transplant and reduced ventilation times (when compared to single lung perfusion at our institution; data not published). Only one patient in this group required extracorporeal membrane oxygenation (ECMO). These observations seem to support our hypothesis that controlled reperfusion may have clinical benefit in lung transplantation and the clinically significant incidence of severe reperfusion injury. Our approach:

1. reduces the ischemic time with controlled warm reperfusion for the first allograft for CPB supported double-lung transplant;
2. precise control of flow into the new grafts;
3. avoiding sudden bursts of high pressure blood flows into cold ischemic tissue. Following implantation of the first allograft, reperfusion is started in a controlled fashion while the remaining allograft is implanted. This is a modification to going on ‘partial bypass’ to reperfuse, which is preferred by some institutions [5] after the first allograft anastomosis is complete.

4. Discussion

During partial bypass, the venous drainage to the CPB machine is partially impaired; blood backs up, fills the right atrium, right ventricle, then perfuses the pulmonary vascular circuit. Partial bypass is, however, not a controlled function. Flow through the pulmonary artery can vary based on right heart contractility, amount of pre-load offered by partial bypass, the patient’s total blood volume, pulmonary vascular resistance, CO2 tension, bypass flow/output, and shunting. Distorting the heart radically alters regulated flow. There may be inadequate or even no flow. In the setting of no flow, the lung suffers from warm ischemia until the patient is weaned from CPB.

Our technique controls the flow and pressure through the reperfused allograft with precision (washout at 100 cc/min for 20–60 min), which may limit interstitial edema by maintaining a perfusion pressure of <20 mmHg in the newly implanted graft. Correction of cellular ischemia may help prepare the PA vasculature for resumption of full PA hydrostatic pressures during the wean off CPB and in turn stabilize or improve gas exchange. A second advantage is the uninterrupted decompression of the right heart in a patient population commonly demonstrating right ventricle dysfunction and pulmonary hypertension. Furthermore, the pro-inflammatory milieu from reperfusion injury and a CPB circuit is minimized since all blood reaching the perfused single lung is washed and filtered (through a 70-kDa filter) prior to perfusing the implanted lung.

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References