

Use of Extracorporeal Membrane Oxygenation during Resection of Tracheal Papillomatosis

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WE present two cases of the use of veno-venous extracorporeal membrane oxygenation (VV-ECMO) during resection of obstructing tracheal papillomata. Conventional anesthesia techniques may be unsafe with near obstructing papillomatous disease of the trachea. The advantage of ECMO in this circumstance is that gas exchange can be totally supported for the duration of the procedure while at the same time providing an apneic unobstructed surgical field. There are reports of the use of ECMO during surgery for tracheal obstruction and resection in neonates and children,^{1,2} but to our knowledge this is the first account of its use in adults.

Case 1

A 46-yr-old man presented with a 4-week history of wheeze and dyspnea. His past medical history included microlaryngoscopy for papilloma of the vocal cords and obesity (weight 152 kg, body mass index 44). He presented acutely having had two community collapses, which were treated successfully with bystander cardiopulmonary resuscitation. He was investigated for possible pulmonary embolism with a computed tomogram pulmonary angiogram. This test was negative for pulmonary embolism but demonstrated a 2.3 by 2.8 cm intratracheal mass 2.5 cm above the carina, which was causing near-complete tracheal obstruction. Awake flexible fiberoptic bronchoscopy demonstrated vocal cord papillomata and a large friable tissue mass 2.5 cm proximal to the carina. Histology of the lesion confirmed infection with human papilloma virus. He was scheduled for laser resection of the tracheal mass.

Informed consent for ECMO and general anesthesia were obtained after an in depth discussion.

The management plan included instituting VV-ECMO prior to induction of general anesthesia. The patient was not premedicated. A heparin bolus of 65 IU/kg was given followed by percutaneous insertion of venous cannulae, performed under local anesthesia. A 25 French (Fr) Multiport (Medtronic, Minneapolis, MN) drainage cannula was placed in the right femoral vein, and a 21 French Medtronic return cannula was placed in the right internal jugular vein. VV-ECMO circulation was

commenced at 6 l/min (2.4 l/min⁻¹m⁻² based on estimated lean body mass) with 6 l/min sweep gas flow at 100% oxygen. Anesthesia was then induced and maintained with propofol using a target controlled infusion (4 mcg/kg) and fentanyl (1.5 mcg/kg plus 0.5-1.0 mcg/kg bolus at hourly intervals). Paralysis was maintained to prevent coughing using rocuronium 0.6 mg/kg as an initial bolus with induction then 0.2 mg/kg approximately hourly thereafter. The ECMO circuit consisted of a polymethylpentene membrane oxygenator (Quadrox, Maquet Cardiopulmonary, Rastatt, Germany), centrifugal pump (Rotaflow, Maquet Cardiopulmonary), and heparin bonded tubing (Medtronic). The circuit was primed with 700 ml Plasma-Lyte-148 (Baxter Healthcare Corp, Deerfield, IL), 1,000 IU of heparin, and 10 ml of molar sodium bicarbonate. ECMO circuit monitoring consisted of inlet pressure, oxygen saturation of blood in the drainage cannula, gas sweep flow, circuit flow, pump speed, and hematocrit. ECMO monitoring data are shown in table 1. Activated clotting time was measured every 5 min for the initial 15 min then 15 min thereafter. The activated clotting time was between 190-250 s throughout the case. No additional heparin was given. In addition to standard anesthesia monitoring, invasive pressures were measured from a right radial arterial catheter and left internal jugular vein central venous catheter. In addition, a processed electroencephalogram (BIS, Aspect Medical Systems, De Meern, The Netherlands) was monitored throughout and kept within the range 25-40. The patient's arterial oxygen saturation (S_aO₂) was 96-97% throughout the period of apnea.

The larynx was exposed using a rigid Storz Kleinsasser D laryngoscope (Karl Storz GmbH & Co. KG, Tuttlingen, Germany) and the tracheobronchial tree visualized with the fiberoptic bronchoscope. A Microdebrider Xomed Tricut 4 mm blade, (Medtronic ENT, Jacksonville, FL) was used to remove the papillomatous tissue from the larynx. With the use of a rigid Storz 8.5 mm bronchoscope (Karl Storz GmbH & Co.), papillomatous necrotic material in the trachea was removed with the rigid forceps under direct and telescopic vision. A Neodymium YAG laser (Medilas Fibretom 8100; Dornier MedTech Europe GmbH, Wessling, Germany) was applied to the papilloma bed once all of the bulk of the tumor had been removed. Surgical duration was 3h.

At the end of the resection the patient's trachea was intubated with a size 8.0 endotracheal tube, and he was ventilated with positive pressure ventilation. ECMO was discontinued, protamine, 100 mg, was given, and the cannulae were removed. The patient was transferred to the intensive care unit sedated with a propofol infusion (250 mg/h) and mechanically ventilated. Twenty-four hours later, fiberoptic bronchoscopy was performed to rule out swelling, bleeding, and residual disease, after which the patient was awoken and extubated. The patient bled minimally and required no blood product transfusion. He was discharged home after 2 days. Ten days later, under general anesthesia, several small papillomata remnants and the "stalk" of the major lesion were removed with a Neodymium YAG laser. A sole complication from the ECMO was a neuropraxia of the lateral cutaneous nerve of the right thigh.

Case 2

A 57-yr-old man with known obstructing tracheal papillomata (fig. 1 and 2) was referred for resection. His comorbidities included severe bronchiectasis, obesity (weight 116 kg, body mass index 38), chronic

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Table 1. Extracorporeal Membrane Oxygenation Circuit Data for Case 1

Hours	ECMO Circuit Flow, l/m	Inlet Pressure, mmHg	SvO ₂ %	Gas Sweep, l/m	FiO ₂	ACT Seconds	PaO ₂ KPa	PaCO ₂ KPa	Hematocrit
0	5.7	-126	72	6.5	1.0	198	10.7	6.1	0.34
0.5	6.2	-130	72	6.5	1.0	199	7.3	5.7	0.33
1.0	6.5	-175	74	5.0	1.0	198	7.5	6.2	0.34
1.5	6.2	-170	67	5.0	1.0	195	6.7	6.2	0.32
2	6.3	-166	69	5.0	1.0	284	6.6	6.3	0.30
2.5	6.2	-175	67	5.0	1.0	243	7.1	6.9	0.29
3.0	6.2	-170	68	5.0	1.0	200	11	6.2	0.29

ACT = activated clotting time; ECMO = extracorporeal membrane oxygenation; FiO₂ = fraction of inspired oxygen; l/m = liters per minute; PaCO₂ = arterial carbon dioxide partial pressure in Kilo Pascals; PaO₂ = arterial oxygen partial pressure in Kilo Pascals; SvO₂ = oxygen saturation in ECMO drainage cannula.

obstructive pulmonary disease, hypertension, type II diabetes, and chronic renal impairment.

One month earlier, the patient had undergone rigid bronchoscopy under general anesthesia at another institution. During this procedure, as the bronchoscope was passed through the papillomata (which extended from 2 cm below the vocal cords to just above the carina), a small amount of bleeding occurred causing total airway obstruction and a hypoxic cardiac arrest. He was successfully resuscitated without sequelae. Due to worsening stridor and hypoxemia he was transferred to our institution for further evaluation and treatment. Informed consent for ECMO and general anesthesia was obtained.

Endoscopic laser removal of his papillomata was planned under general anesthesia with VV-ECMO support. Anesthesia and perfusion management were the same as in the first case. ECMO monitoring data are shown in table 2. A Storz rigid Kleinsasser D laryngoscope was placed in the airway allowing a good view of the larynx and providing easy access to the trachea for the flexible bronchoscope. The extensive laryngeal and tracheal papillomata were removed with a Neodymium YAG laser using a coagulation/ablation technique. There was minimal bleeding. Surgery took 6 h. At the end of the procedure ECMO was discontinued, heparin was reversed with protamine 50 mg, and the patient's trachea was intubated with a size 8.0 endotracheal tube. He was then transferred to the intensive care unit sedated and ventilated. The following day, bronchoscopy with suspension laryngoscopy and further laser surgery were performed to remove remnants of papillomata. Following this procedure the patient was awoken and extubated without complication. Four days later he was discharged home on humidified oxygen for outpatient follow up. No blood products were administered.



Fig. 1. Mid-tracheal bronchoscopic view of second case.

Discussion

Options for airway management during anesthesia for surgery of tracheal papillomata include apnea with intermittent bag mask ventilation; use of a ventilating bronchoscope, jet, or spontaneous ventilation with suspension laryngoscopy; and use of a laser-protected endotracheal tube with ventilation.³ These options are extremely challenging in the presence of morbid obesity and significant tracheal obstruction.

Our goal was to maintain normal gas exchange at all times while allowing unobstructed surgical access to the trachea, recognizing that a lengthy procedure was likely given the extent of resection required in these two patients. An apneic technique reduces aerosolisation of virus particles, which minimizes operating room staff exposure. In addition, an apneic technique may reduce distal seeding of virus to the small airways, although this is debated.^{4,5} VV-ECMO allows this exact situation and obviates the risks of hypoxemia due to airway loss, which is a very real possibility with the above described anesthesia techniques. Normal gas exchange can be



Fig. 2. Sagittal computed tomographic image of mid-tracheal papillomata of second case.

Table 2. Extracorporeal Membrane Oxygenation Circuit Data for Case 2

Hours	ECMO Circuit Flow, l/m	Inlet Pressure, mmHg	Gas Sweep, l/m	FiO ₂	ACT Seconds	PaO ₂ KPa	PaCO ₂ KPa	Hematocrit
0	5.3	-77	5.2	1.0	165	16.5	6	0.34
0.5	5.2	-75	4.9	1.0	158	9.1	5.9	0.37
1.0	5.0	-80	4.5	1.0	140	8.2	5.5	0.37
1.5	5.1	-78	4.0	1.0	210	8.6	5.6	0.38
2.0	5.1	-80	4.0	1.0	191	9.1	5.9	0.38
2.5	5.1	-80	4.0	1.0	165			
3.0	5.1	-83	4.0	1.0	178			
3.5	5.3	-79	4.3	1.0	136	8.8	6.7	0.37
4.0	5.2	-78	4.3	1.0	136	9.8	6.6	0.37
4.5	5.3	-73	4.3	1.0	140	13.5	6.4	0.37

ACT = activated clotting time; ECMO = extracorporeal membrane oxygenation; FiO₂ = fraction of inspired oxygen; l/m = liters per minute; PaCO₂ = arterial carbon dioxide partial pressure in Kilo Pascals; PaO₂ = arterial oxygen partial pressure in Kilo Pascals; SvO₂ = oxygen saturation in ECMO drainage cannula.

achieved despite total apnea, and the surgeon has an operative field clear of any airway equipment.

There are several possible techniques for VV-ECMO.⁶ With our approach, deoxygenated blood was drained from the inferior vena cava *via* a large-bore cannula placed in the femoral vein. Blood passed first to an oxygenator (containing an integrated heat exchanger) and then to a centrifugal pump. Oxygenated blood was then returned to the patient *via* a cannula placed in the internal jugular vein. In this circumstance, the patient's arterial oxygen saturation (S_aO₂) depends on ECMO flow, native cardiac output, and oxygen consumption. With ECMO flows of 2–3 l/min⁻¹m⁻², and assuming normal values of cardiac output and oxygen consumption, S_aO₂ values of 85–95% can be achieved in the absence of any pulmonary ventilation.

Veno-arterial ECMO, in which the return cannula is placed in a large artery, usually the femoral, may have been used as an alternative to VV-ECMO. However, there are several disadvantages with using veno-arterial ECMO in this circumstance. First, a femoral arteriotomy is required, which may cause localized bleeding, distal limb ischemia, and arterial gas embolism. Second, if ECMO circuit flow is too low, there may be significant blood flow through the (nonventilated) lungs, which can cause upper body (coronary and cerebral) hypoxemia.⁷ Another alternative to VV-ECMO is conventional cardiopulmonary bypass (CPB). However, in addition to the disadvantages of veno-arterial ECMO, CPB, which contains a venous reservoir with an air-blood interface, is associated with a high risk of coagulopathy and systemic inflammation.⁸ CPB is also known to adversely affect pulmonary and renal function due to leukocyte sequestration and activation.⁹ The second patient, who required 6 h of surgery, would have been particularly at risk of these problems if conventional CPB had been used.

There have been two reports of adult patients undergoing tracheal resection for severe papillomatous disease on CPB.^{10,11} However, there was limited documentation regarding the use of CPB and its complications in these two reports. A further report describes the use of percutaneous femoro-femoral veno-venous CPB in two pa-

tients undergoing carinal resection for malignancy.¹² In this report, CPB was not required for induction of anesthesia, but was used to provide an unobstructed operative field during surgical resection. This is in contrast to our cases in which induction of general anesthesia without ECMO was considered unsafe.

The relative risks of conventional anesthesia techniques for tracheal surgery in high risk patients *versus* those of extracorporeal circulation must be considered. In some cases, as presented above, ECMO is likely to be the safest option for managing the airway and maintaining gas exchange. Referral to ECMO capable centers is appropriate if the severity of airway disease indicates that total tracheal occlusion is likely with conventional methods of airway management under anesthesia. A multidisciplinary approach, coordinated preoperatively, allows optimal management and patient safety.

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