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Retention of a Migrated Avalon Cannula for Acute Conversion to Dual-Site Venovenous Extracorporeal Membrane Oxygenation

Case Report

Abstract

The use of dual-lumen catheters (DLC) for single site venovenous extracorporeal membrane oxygenation (ECMO) has developed into a promising method of treatment to support patients with acute respiratory distress syndrome (ARDS). However, the complexity of the catheter placement still provides a basis for complications, making visual guidance an essential part of the implantation procedure. An incident of post-deployment cannula migration into the right ventricle in conjunction with coagulative disorders is reported, which required acute conversion to venovenous dual-site ECMO. The case exemplifies that, under certain circumstances, repositioning of the cannula is not always a feasible option. A reliable alternative is proposed to re-establish adequate ECMO therapy while retaining the initially introduced DLC.

Keywords

Venovenous, ECMO, dual-lumen catheter, Avalon, migration, conversion

Zusammenfassung

Die Verwendung von Doppellumenkathetern (DLC) zur Etablierung von venovenöser extrakorporaler Membranoxygenierung (ECMO) über nur eine Implantationsstelle hat sich zu einer vielversprechenden Behandlungs- bzw. Unterstützungsmethode bei Patienten mit akutem Atemnotsyndrom (ARDS) entwickelt. Dennoch können aufgrund der Komplexität des Kanülierungsvorgangs Komplikationen hinsichtlich der Positionierung des Katheters auftreten, sodass die Zuhilfenahme bildgebender Verfahren einen essentiellen Bestandteil der Implantation darstellt. Im Rahmen dieses Fallberichts wird die Migration eines DLC nach zunächst erfolgreicher ECMO-Implantation in den rechten Ventrikel bei gleichzeitiger Entwicklung einer systeminduzierten Koagulopathie vorgestellt und darüber hinaus die Notwendigkeit einer akuten Konversion zur konventionellen ECMO-Therapie beschrieben. Anhand dieses Vorfalls wird deutlich, dass die Repositionierung einer migrierten Kanüle unter gegebenen Umständen ein hohes Risiko mit sich führen kann. Die hier präsentierte Vorgehensweise einer Konversion zur konventionellen ECMO bietet eine sichere Alternative zur Wiederherstellung adäquater Unterstützungstherapie und ermöglicht zudem die Erhaltung des initial eingeführten DLC.

Schlüsselwörter

Venovenös, ECMO, Doppellumenkatheter, Migration, Konversion

Overview

Facilitating respiratory support in patients where conventional treatment fails, the increasing interest in venovenous extracorporeal membrane oxygenation (ECMO) has revolutionized the management of patients with acute respiratory distress syndrome (ARDS) [1,2]. In their conventional configuration, ECMO circuits require dual peripheral cannulation of either both femoral veins or a femoral and internal jugular vein (IJV) to facilitate drainage from the inferior vena cava and reinfusion into the right atrium, respectively. However, the proximity of the inflow and outflow cannulas may result in recirculation associated with insufficient oxygenation of the blood. The Avalon Elite (Avalon Laboratories, Los Angeles, CA, USA) dual-lumen catheter (DLC) allows for single-site. ECMO utilizing the right IJV for percutaneous intracaval access. The outflow lumen is connected to two circumferential drainage ports which are located proximally in the superior vena cava and at the distal tip of the catheter for placement below the inferior cavo-atrial junction. The inflow lumen propels blood through the medial side port facing the tricuspid valve within the right atrium, thereby minimizing reperfusion and shunting as oxygenated flow is directed into the right heart [3]. While further benefits of this single-site approach in consideration of long-term support include the earlier patient mobilization due to the prevention of femoral cannulation, adequate positioning of the DLC can be difficult despite the visual support by imaging techniques such as fluoroscopy or transesophageal echocardiography (TEE) [3,4]. This case report describes an incident of post-deployment cannula migration coupled with coagulative disorder and aims to illustrate the resulting conversion procedure from single- to dual-site ECMO.

Description

A 46-year-old male (74 kg, 186 cm) was presented to the emergency room with severe dyspnoea and impaired cardiorespiratory function. A primary ciliary dyskinesia associated with an influenza infection, ultimately resulting in the development of acute ARDS, was diagnosed subsequent to admission. Following emergency intubation, extracorporeal support in the form of ECMO was implanted utilizing a 27 Fr Avalon DLC (Avalon Elite, Avalon Laboratories, CA, USA) for venovenous access. Prior to the cannulation of the right IJV, a

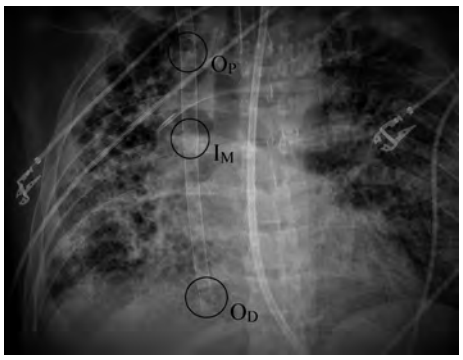

Figure 1: Post-deployment chest radiograph confirming adequate cannula position, with the distal outflow port (OD) resting within the inferior vena cava, the medial inflow port (IM) facing the tricuspid valve and the proximal outflow port (OP) situated in the superior vena cava

	pH	Hb (g/dl)	pO_2 (mmHg)	pCO_2 (mmHg)	Tbc. (nl-1)	LDH (U/l)	d-dimers (ng/ml)	Fibr. (mg/dl)
Pre-ECMO implantation	7.09	12.2	76	112	293	503	<500	600
Post-ECMO implantation	7.29	11.0	131	50.9	215	458	2120	499
4 days of ECMO therapy	7.29	9.6	71	60.1	136	481	39547	398
Post system replacement	7.32	8.6	64	44	182	445	5554	448
Post dual-site conversion	7.37	9.3	145	37	190	405	7500	429

Table 1: Development of the patients' blood gas and coagulation parameters. Tbc.: Thrombocytes, LDH: lactate dehydrogenase, Fibr.: Fibrinogen

bolus of 5000 I.U. of heparin was administered. The introduction of the DLC into the incrementally dilated vessel was then carried out guided by TEE to assure correct placement within the right atrium and the caval veins, respectively (fig. 1). The ECMO system consisted of a centrifugal pump (Rotaflow, Maquet, Rastatt, Germany), a membrane oxygenator (PLS-i-oxygenator, Maquet, Rastatt, Germany) and ⅜-inch coated tubing (Bioline, Maquet, Rastatt, Germany). The total priming volume was 585 ml, and a flow of 45 ml/kg/min was established without issue. The integrated Heater Unit (HU35, Maquet, Rastatt, Germany) regulated the patient's core temperature to 37 °C. Throughout the implantation procedure, the blood pH remained within the range of 7.0 as a response to the hypoxic and hypercapnic respiratory failure (Table 1), normalizing shortly after initiating ECMO with no significant rise in the concentration of lactate. To maintain a mean arterial pressure (MAP) of 60 mmHg a moderate catecholamine support was required. An activated partial thromboplastin time of 50–60 s was sustained. After four days of uneventful therapy, the derangement of certain coagulation parameters, specifically a decline in the platelet count as well as the fibrinogen concentration combined with an increase of d-dimers and lactate-dehydrogenase (Table 1) was detected. These changes were seen as an indication for the formation of blood clots in the ECMO circuit and led to the preventive replacement of the system. Nevertheless, ECMO therapy became increasingly insufficient, with arterial saturation dropping to 80 %. The daily chest radiograph revealed that the DLC migrated into the right ventricle, thereby creating a shunt between its distal drainage port and the afferent medial port (fig. 2). Attempts to reposition the cannula under visual guidance have been proven to be unsuccessful, and the risk associated with the potential reimplantation was considered too high. In order to restore suitable ECMO support, a second cannula (Bio- Medicus 23 Fr, Medtronic, MI, USA) was placed into the right femoral vein and advanced towards the bifurcation, thereby serving as an alternative venous return. Already situated in the right IJV, the DLC was retracted as far as possible to exclusively provide arterial blood to the patient. For this purpose, ECMO was briefly stopped and the tubing lines were clamped at the oxygenator outflow, the centrifugal pumps inflow, as well as both the arterial and venous lines approximately 30 cm of the DLC. Following transection, the lines coming from the DLC's inflow and outflow ports were merged by means of a ⅜-inch y-connector (fig. 3). This allowed for the arterial line of the ECMO system to be reconnected while carefully avoiding air entrapment. In the final step, the venous line was connected to the femoral cannula and the conventional venovenous dual-access ECMO circuit was re-established. During the conversion which lasted less than 30 seconds, the patient remained hemodynamically stable. No arrhythmia was detected, and the MAP experienced a slight decrease of 15 mmHg for a short period of time. Analysis of the blood parameters suggested an immediate improvement, with an arterial pO_2 measured at 150 mmHg and the saturation reaching 95 %. As a result, the therapy was continued without further complications regarding ECMO. Unfortunately, the persisting decarboxylatory dysfunction accompanied by cachexia and multi-organ failure made lung transplantation or weaning from ECMO unfeasible, and the therapy was terminated after 40 days.

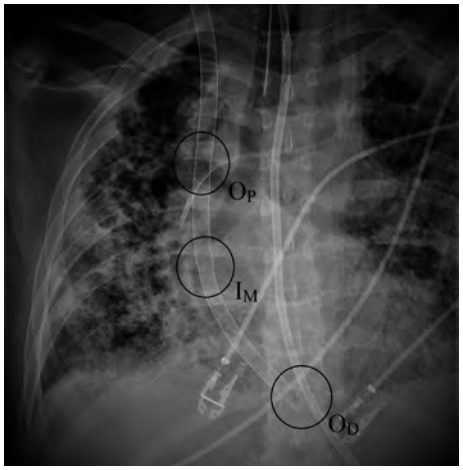

Figure 2: Chest radiograph revealing the cannula migration into the right ventricle, indicated by the distinctive displacement of the distal outflow port (OD) in medial direction as well as the caudal shift of both the proximal outflow port (OP) and the medial inflow port (IM).

Figure 3. Branching of the arterial line to access both lumens of the maintained and retracted Avalon cannula for converted venovenous dual-site ECMO.

Comments

Although less expeditious and more expensive, the use of DLC for venovenous ECMO offers distinct advantages, including a reduced potential for recirculation as well as better mobilization of the patient when compared to the conventional approaches via femoro-jugular and femoro-femoral cannulation [3]. The correct placement of the cannula utilizing imaging techniques represents the most important aspect of

the procedure and requires a highly experienced team [3,4]. According to the literature, most complications occurring during treatment are related to migration or malpositioning of the cannula, with severe cases of acute cardiac tamponade due to right atrial or ventricular perforation being reported, involving immediate surgical repair [5–7]. It has been described that migration of the DLCs distal port into either the right atrium or ventricle can result in recirculation and subsequent hypoxemia [3,7,8], whereas placement of the cannula in the hepatic vein caused impairment of ECMO flow [3–5,8]. In contrast to the presented case, none of the previously published case reports related to a cannula migration specifically documented the necessity of modifications to the ECMO circuit as a direct response to the initial complication since all events were successfully resolved by repositioning the catheter's distal portion under visual guidance. Choosing the appropriate cannula size based on the patient-specific calculation of the blood flow was essential to ensure the proper placements of its distal end past the inferior cavo-atrial junction (fig. 1), which has been assumed to be the determining factor regarding the emergence of cannula movement into the right heart [7]. Due to excessive suction, a perforation of the DLC may have occured. Thus, the tolerated degree of manipulation was compromised, resulting in the failure to readjust the cannula position. Considering the susceptibility of the insertion site, extraction of the cannula was associated with a high risk of bleeding, delay of therapy and even death due to the necessity for the replacement of the ECMO circuit. Conversion to conventional venovenous femoro-jugular dual-site ECMO while retaining DLC function was seen as the safest and fastest way to remedy the situation. To avoid right heart decompensation caused by excessive volume overload to the right ventricle after the conversion, retraction of the DLC is strongly advised. The specified approach can be carried out without the availability of an operation theatre, therefore making it exceptionally feasible in acute scenarios. Furthermore, excellent coordination between the cardiac surgeon and perfusionist is crucial to minimize the downtime of the extracorporeal support and to maintain hemodynamic stability. In addition, patient mobilization is restrained due to the introduction of a femoral cannula. Regarding the reappearance of recirculation during dual-site ECMO, it is the clinics common practice to place femoral drainage cannulas just above the femoral bifurcation, thereby eliminating steal phenomena while facilitating adequate flows for successful ECMO therapy. It was unclear to what extend the migration of the catheter affected the coagulative dysfunctions, as both episodes were independently discovered within a day. Hemolysis induced by high negative pressures or flow velocities in small lumen cannula during ECMO is an unusual anomaly. Sharp flow profiles and changes in direction between the recirculating ports of the DLC may have resulted in increased shear stress and destruction of red blood cells. However, no significant elevation in free hemoglobin concentration was detected and ECMO flow was kept within the catheter's specified range. Instead, the gradual accumulation of d-dimers coupled with device-induced hyperfibrinolysis suggested the manifestation of disseminated intravascular coagulation. Ultimately, the presented case demonstrates that in given certain circumstances, cannula repositioning is not always feasible and conversion to dual-site ECMO offers a smart alternative method. The relevance of changes to the ECMO circuit should be further explored and discussed, as the adaptability can provide additional safety when utilizing DLC.

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