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Radiologic Technologist Approach to the Patient on Extracorporeal Membrane Oxygenation

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Abstract

Extracorporeal membrane oxygenation (ECMO) is a form of temporary circulatory support in patients with impaired heart and / or lung function, in whom conventional methods of treatment have been exhausted. ECMO support does not treat the underlying pathology, but allows oxygenation and perfusion of vital organs until complete recovery or as a destination therapy for heart and / or lung transplantation. It is an integral part of modern intensive care for patients with severely impaired cardiac and / or respiratory function. Medical staff involved in the treatment and monitoring of patients on ECMO support should be familiar with the basics of the ECMO system, in accordance with the workplace and with approach to the patient on ECMO support. A radiologist who performs a radiological examination in such a patient requires cooperation with the anaesthesiology team and the team of perfusionists, so that the basic conditions for performing the examination are met and the examination is successfully performed. The aim of this paper is to acquaint radiological technologists with the approach to the patient on ECMO support and to present the experiences of the Radiology Department at Clinical Hospital Centre Rijeka in performing radiological examinations on such patients. Data are collected through hospital databases and are related to the demographic characteristics of patients and indications for performing computed tomography (CT) examinations. Patients were selected according to the type of ECMO support and according to the region of interest for performing a CT scan in the period from 1st January 2017 to 15th August 2019.

Keywords: Extracorporeal membrane oxygenation, perfusion, computed tomography, radiological examinations.

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Introduction

Extracorporeal membrane oxygenation (ECMO) is a modified cardiopulmonary bypass that maintains continuity of circulation, allowing further patient care and recovery during severe heart and/or lung failure. Several studies have shown that ECMO saves human lives in a variety of clinical conditions, and its use has expanded significantly over the last two decades [1]. As the technology of the device advances, and the needs for using ECMO support are increasing, there is a growing need for the education of personnel of different profiles in health care [2]. The first long-term ECMO procedure was successfully performed in 1972 in an adult patient with post-traumatic respiratory failure [3]. After many years of perfecting ECMO procedures and conducting randomized studies in which the effectiveness of ECMO procedures has been proven, ECMO procedures are becoming the standard of modern intensive care [4]. The pandemic of influenza caused by the H1N1 virus has led to the wider use of ECMO support,

proving its effectiveness in respiratory failure. The results obtained during this pandemic have led to the acceptance of the use of "membrane lungs" worldwide [5]. As the patients undergoing ECMO procedure require continuous monitoring and assessment of clinical status, one way of assessing the clinical status is computed tomography (CT), as the most often performed radiological diagnostic method [6].

In order to better understand the work principle and cannulations in ECMO support, it is essential to be familiar with the anatomy and physiology of the circulatory system. The function of the circulation is to fulfil tissue needs – it transports nutrients and oxygen, and removes waste products of metabolism. The circulatory system is divided into systemic and pulmonary circulation. The systemic circulation supplies blood to all tissues in the body except the lungs and is often referred to as the large bloodstream or peripheral circulation. Pulmonary circulation indicates the flow of blood between the heart and lungs and its primary function is blood oxygenation and it represents a very important link between the vascular and respiratory systems. From the right ventricle, venous blood travels through the pulmonary arteries to the lungs, where gases are exchanged at the capillary level and oxygenated blood is returned to the left atrium through the pulmonary veins. From the left atrium, oxygenated blood travels through the aorta and its branches to the periphery, where nutrients and oxygen are also exchanged at the capillary level. Deoxygenated blood is returned to the heart by veins (ultimately via the superior and inferior vena cava), after which it undergoes pulmonary circulation again [7].

Methods and materials

ECMO Support Modalities

There are two basic modalities of ECMO support: veno-venous ECMO (VV ECMO) and veno-arterial ECMO (VA ECMO). VV ECMO serves as a support in case of severe reversible respiratory failure in patients in whom there is no major cardiac dysfunction. In VV ECMO support, deoxygenated blood is drained from the patient through an access cannula, which is usually placed through the femoral vein into the inferior vena cava, while oxygenated blood is returned to the venous system through a return cannula, which is usually placed through the jugular vein near the inflow of the superior vena cava into the right atrium.

VA ECMO provides complete hemodynamic and respiratory support [8]. In VA ECMO support, deoxygenated blood is drained from the venous circulation by a cannula that is most commonly placed into the inferior vena cava or femoral vein, and oxygenated blood is returned to the systemic circulation most commonly through the femoral artery [3].

Like any medical or diagnostic procedure, the ECMO procedure has certain contraindications [4]. Contraindications for performing the ECMO procedure can be absolute or relative.

Absolute contraindications are:

- Heart failure without the possibility of recovery, when the patient is not a candidate for transplantation or VAD support
- Disseminated malignant disease
- Severe brain injury
- Cardiac arrest when the time of occurrence is unknown
- Prolonged cardiopulmonary resuscitation (CPR) without adequate tissue perfusion
- Untreated aortic dissection
- Severe aortic regurgitation
- Severe chronic organ dysfunction (emphysema, renal failure, liver cirrhosis)
- Peripheral vascular disease is a contraindication for peripheral VA ECMO
- VV ECMO is contraindicated in patients with heart failure and severe chronic pulmonary hypertension (> 50 mmHg)

Table 1. Indications for the ECMO procedure [4]

Indications for ECMO procedure	
VA ECMO	**VV ECMO**
• cardiogenic shock or severe heart failure of various aetiologies • after cardiotomy – inability to separate from cardio-pulmonary bypass after heart surgery • after heart transplantation – primary graft failure after heart or heart and lung transplantation • chronic cardiomyopathy – as a destination therapy • before high-risk PCI procedures • destination therapy to support patients until heart transplantation	• acute respiratory distress syndrome of various aetiologies • extracorporeal support to relieve lung relief (airway obstruction, smoke inhalation, lung contusion, etc.) • after lung transplantation – primary graft insufficiency • destination therapy to support patients until lung transplantation • hyperinflation of the lungs in asthmatic status • pulmonary haemorrhage or massive haemoptysis • congenital diaphragmatic hernia, meconium aspiration

Relative contraindications for ECMO are contraindications for anticoagulant therapy, uncontrolled bleeding, obesity, older age of the patient, or comorbidities due to which the patient has a poor prognosis for recovery [3,9].

Radiologic Technologist Approach to the Patient on Extracorporeal Membrane Oxygenation

Since the ECMO procedures are applied to patients with life-threatening condition which requires 24-hour monitoring and continuous assessment of clinical status, such patients are placed in the intensive care unit (ICU). One way to assess the clinical status of patients undergoing ECMO procedure is to perform a CT examination according to the indication and request of the anaesthesiologist. In patients on ECMO support at the University Hospital Centre Rijeka, most often performed diagnostic procedure is post contrast high resolution or standard CT scan of the thorax with frequent referral diagnosis of acute respiratory distress syndrome (ARDS). CT scans of the brain, abdomen and pelvis and angiographies are somewhat less frequently performed.

In addition to performing CT scans, standard radiological procedures include an radiograph of the heart and lungs and a AP supine abdominal radiograph. As imaging is performed with a portable X-ray machine, in a supine position and with restrictive technical conditions, such images are considered orientational, as they serve to assess the position of the catheters, ECMO cannulas and the status of the thoracic organs [10].

Standard radiographs of the heart and lungs are important in the clinical evaluation of such patients because they usually reveal the first signs of complications of the ECMO procedure such as hemothorax, pneumothorax, pleural effusions, or hematomediastinum [11].

In classic radiographs, the imaging is performed in such a way that the detector is placed under the patient lying on a hospital bed. Prior to performing imaging, radiologic technologist must protect other patients from possible scattered radiation with a lead screen, and then, with the supervision and assistance of ICU staff, place a detector under the patient to be imaged. The detector is placed with special care and precision, to avoid unnecessary exposure due to inadequate patient or detector positioning. Patients on ECMO support in the intensive care unit, in addition to ECMO cannulas, usually have central venous catheters, urinary catheters, endotracheal tubes, ECG electrodes, etc., and such patients should be handled with care, with the help and supervision of ICU staff. The imaging itself is performed with standard exposure parameters and with standard post-processing.

Performing a CT scan of a patient on ECMO support is demanding for the radiologic technologist, primarily in

Table 2. Performing a CT scan of a patient on ECMO support at the Clinical Department of Radiology, Clinical Hospital Centre Rijeka

PERFORMANCE OF CT SCAN IN PATIENTS ON ECMO SUPPORT	
THORACIC CT	• standard or high resolution protocol • post contrast (after consultation with the radiologist) • in the maximum possible inspiration • slightly more contrast agent with slightly higher flow, depending on the patient and the ECMO procedure (standard: biphasic application of CM; 75 ml – 40 ml 1.2 ml / s, 35 ml 2.5 ml / s) • most common indication: assessment of ARDS
CT ANGIOGRAPHY	• standard protocol for performing CT angiography • bolus tracking technique – ROI in the descending aorta • most common indication: assessment of peripheral hypoperfusion
BRAIN CT	• native (post-contrast only in consultation with a radiologist) • most common indications: difficulty waking the patient from sedation, assessment of hypoperfusion, oedema
ABDOMEN AND PELVIS CT	• native – to assess cannulas position • post contrast standard protocol for assessing visceral organ perfusion
CT OF THE NECK ORGANS	• native or post-contrast in consultation with the radiologist, depending on the clinical issue • most common indication: assessment of the position of the endotracheal tube

terms of patient manipulation and requires close cooperation and coordination of the radiologic technologist with the anaesthesiology team and the team of perfusionists. The time of arrival of the patient for the CT examination must be precisely defined, since the entire examination takes longer than usual and the coordination between the three teams is essential. Transfer of the patient to the CT table is performed under the guidance of an anaesthesiologist and perfusionist where the anaesthesiologist takes care of the endotracheal tube (to avoid extubation of the patient during patient manipulation) while the perfusionist takes care of ECMO cannulas (to prevent separation of the cannula from the patient). Anaesthesiology technicians take care of the placed arterial line and accompanying devices for continuous therapy and patient monitoring, while the radiologic technologist takes care of the correct positioning of the patient for imaging, in order to minimize the need for additional adjustment. Positioning of the patient for the brain scan requires the least manipulation, while imaging of the thorax and abdomen, or angiography requires slightly more manipulation, in terms of placing the patient's hands in the optimal position for imaging and removing accompanying therapy and monitoring devices from the region of interest. If it is necessary to apply contrast agent, the radiologic technologist, with the help of an anaesthesiologist or anaesthesiology technician, selects an accessible and adequate venous route, i.e. the part of the central venous catheter which it is then connected to the automatic injector [12].

If contrast agent is administered via a peripheral vein, it is important to remove the cuff of the blood pressure monitor if it is above the place setting of intravenous cannula. If radiologic technologist does not pay attention to the cuff of the sphygmomanometer, it may happen that at the time of application of the contrast agent, the device begins to measure the pressure, which can cause venous obstruction, rupture of the vein and extravasation of the contrast agent. Once the patient is positioned in a satisfactory imaging position and connected to the automatic injector, the next step is to secure the respirator tubes, endotracheal tube and the ECMO cannulas. Before all team members leave the room and CT scan begins, it is important to check that moving the table doesn't disconnect the endotracheal tube, respirator tubes, and ECMO cannulas. The radiologic technologist, in collaboration with the anaesthesiologist / anaesthesiology technician and perfusionist, slowly moves the table into the CT gantry, constantly checking that it doesn't endanger the patient. Prior to placement in the initial position for the scout, the patient should be positioned in the CT gantry as far as possible, i.e. to the end of the scanned region, in order to assess at what distance from the CT gantry the devices may stand (respirator, ECMO, perfusors, vital signs monitor) without a possibility of forced separation of any segment of the patient's vital support. When all the actions that precede the beginning of the CT scan are performed, radiologic technologist can start executing the CT scan. Like any CT scan, the first step is to perform a scout and plan the scan according to the region of interest. If a post-contrast examination is performed, before applying the contrast agent, and after the examination is completely planed, the radiologic technologist instructs the perfusionist to reduce the flow in the ECMO device to a minimum (standard flow is 3 to 6 l / min) [4]. If the flow on the ECMO device is not reduced during the application of contrast agent, the contrast agent will be withdrawn into the device itself and there will be no opacification of blood vessels and / or organs of interest, which is not technically sufficient and the scan should be repeated. Also, before scanning the thorax, the radiologic technologist should instruct the anaesthesiologist to "clamp" the endotracheal tube after performing maximum inspiration, so that the scan is performed in apnoea, thus avoiding breathing artefacts, and the lung parenchyma is sufficiently ventilated.

After the examination, and before removing the patient from the CT table, the radiologic technologist must determine whether the examination is technically adequate or there is a need to repeat, modify or continue the examination (all in consultation with a radiologist). If the examination is technically adequate and there is no need to continue or modify the examination, the patient is transferred from the CT table to the hospital bed in the same way as before the examination.

Table 3. Performed CT scans in the period from 1st January 2017 to 15th August 2019 at the Clinical Department of Radiology, Clinical Hospital Centre Rijeka

PERFORMED CT SCANS IN PATIENTS ON ECMO SUPPORT (1st January 2017 to 15th August 2019)	
	128 VA – ECMO
	26 VV – ECMO
CT scans in total	103
Thoracic CT scans	48
Abdominal CT scans	7
Pelvic CT scans	4
CT angiographies	8
Brain CT scans	35
CT of the neck organs	1

Conclusion

ECMO support is an integral part of modern intensive care for patients with severely impaired cardiac and / or respiratory function. Medical staff involved in the treatment and monitoring of patients on ECMO support should be familiar with the basic principles of the ECMO system, which is a prerequisite for the successful performance of all work tasks within their competencies. When conducting radiological diagnostic methods, multidisciplinary cooperation is necessary, which in patients on ECMO support implies the cooperation of a radiological technologist with the anaesthesiology team and the team of perfusionists. ■

Sažetak

Izvantjelesna membranska oksigenacija (Extracorporeal membrane oxygenation - ECMO) je oblik privremene cirkulatorne potpore u bolesnika s narušenom funkcijom srca i/ili pluća, kod kojih su konvencionalne metode liječenja iscrpljene. ECMO potpora ne liječi osnovnu patologiju, nego omogućuje oksigenaciju i perfuziju vitalnih organa do potpunog oporavka ili kao destinacijska terapija prema transplantaciji srca i/ili pluća. Sastavni dio modernog intenzivnog liječenja bolesnika s teško oštećenom srčanom i/ili respiratornom funkcijom. Medicinsko osoblje uključeno u liječenje i monitoring bolesnika na ECMO potpori treba biti upoznato s osnovama ECMO sustava, sukladno radnom mjestu te sa pristupom bolesniku na ECMO potpori. Radiološki tehnolog koji izvodi radiološku pretragu kod takvog bolesnika treba suradnju s anesteziološkim timom i timom perfuzionista, kako bi osnovni uvjeti za izvođenje pretrage bili zadovoljeni te pretraga uspješno izvedena. Cilj ovog rada je upoznati radiološke tehnologe s pristupom bolesniku na ECMO potpori te prenijeti iskustva Kliničkog zavoda za radiologiju, Kliničkog bolničkog centra Rijeka (KBC), u izvođenju radioloških pretraga kod takvih bolesnika. Informacije prikupljene iz bolničkih baza podataka odnose se na demografske karakteristike bolesnika i indikacije za izvođenje pregleda kompjutoriziranom tomografijom (CT). Bolesnici su selektirani prema vrsti ECMO potpore i prema regiji od interesa za izvođenje CT pretrage u periodu od 1.1.2017. do 15.08.2019. godine.

Ključne riječi: izvantjelesna membranska oksigenacija, perfuzija, kompjutorizirana tomografija, radiološke pretrage.

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