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Original Article

A technique of hemodialysis in patients with extracorporeal membrane oxygenation

Ekstrakorporeal membran oksijenatörü olan hastalarda bir hemodiyaliz tekniği

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Abstract

Aim: We aimed to evaluate the safety and feasibility of hemodialysis (HD) by using a screw compressor clamp on extracorporeal membrane oxygenation (ECMO) lines without placing a central venous catheter.

Material and Methods: From May 2013 to September 2017, 43 adult patients with ECMO that required renal replacement treatment with HD were included.The inflow of the dialysis machine was connected to the outlet of the oxygenator, and the outflow was connected to the venous line using two 3-way taps. The tool that was used on the outflow circuit to perform HD is a clamp on a screw, allowing us to squeeze and de-squeeze to set the optimal line pressure. Creatinine, blood urea nitrogen, pH, base deficit, lactate dehydrogenase (LDH) values were evaluated, and compared pre/post-HD. Rate and duration of dialysis were also analyzed.

Results: HD was successfully performed in all patients with this technique without additional morbidity and mortality. No related complications due to HD were observed. Blood urea nitrogen, creatinine, pH, base deficit values were decreased to the desired levels after dialysis ($p<0.05$). There was a slight insignificant increase in LDH values after HD ($p=0.446$).

Conclusion: This screw compressor clamp increased the pressure on returning line of HD to the venous ECMO line; and made dialysis and ultrafiltration possible even in low blood pressure. This technique is very simple and allows to perform successful filtration and dialysis using ECMO lines without placing venous catheter.

Keywords: extracorporeal life support; kidney injury; hemodialysis; renal replacement therapy.

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Öz

Amaç: Bu çalışmada santral venöz kateteri yerleştirmeden, ekstrakorporeal membran oksijenasyonu (ECMO) hatlarında farklı bir enstrüman kullanılarak hemodiyalizin (HD) uygulanabilirliliğini ve güvenliliğini değerlendirmeyi amaçladık.

Gereç ve Yöntemler: Mayıs 2013 - Eylül 2017 tarihleri arasında kliniğimizde ECMO takılmış, HD ile renal replasman tedavisi gerektiren 43 yetişkin hasta çalışmaya dahil edildi. Diyaliz makinesinin çıkışı, oksijenatörün venöz hattına, diyaliz makinasının girişi ise ECMO'nun arter hattının çıkışına iki 3-yollu musluklar kullanılarak bağlandı. HD gerçekleştirmek için çıkış devresinde basıncı ayarlamak için kullanılan enstrüman, en uygun hat basıncını ayarlamak için sıkıştırmamıza izin veren bir vida üzerinde bir kelepçe olarak tasarlanmıştı. Kan kreatinin, kan-üre nitrojeni, pH, baz açığı, laktat dehidrojenaz (LDH) değerleri değerlendirilerek HD öncesi ve sonrası karşılaştırıldı. Diyaliz sayısı ve süresi de analiz edildi.

Bulgular: Bu teknikle ek morbidite ve mortalite olmaksızın tüm hastalarda HD başarılı bir şekilde uygulandı. HD'ye bağlı hiçbir komplikasyon görülmedi. Diyaliz sonrası kan üre nitrojen, kreatinin, pH, baz açığı değerleri istenilen seviyeye düştü ($p<0.05$). HD'den sonra LDH değerlerinde istatistiksel olarak hafif derecede anlamlı olmayan bir artış görüldü ($p=0.446$).

Sonuç: Kulandığımız bu enstrüman, venöz ECMO hattından HD hattına olan basıncı arttırdı; düşük tansiyonda bile diyalizi ve ultrafiltrasyonu mümkün kıldı. Basit bir teknik ile çalışan bu alet sayesinde venöz kateter yerleştirmeden ECMO hatları kullanılarak başarılı filtrasyon ve diyaliz yapılması sağlanabilir.

Anahtar kelimeler: ekstrakorporeal yaşam desteği; böbrek hasarı; hemodiyaliz; renal replasman terapisi.

Introduction

Extracorporeal membrane oxygenation (ECMO) is a temporary form of life support providing a prolonged biventricular circulatory and pulmonary support for patients experiencing both pulmonary and cardiac failure unresponsive to conventional therapy [1]. Advances in pump and oxygenator technology, patient selection and cannulation strategies have contributed to expanded utilization of this technology. ECMO is simple to establish and allows rapid recovery of impaired organ functions. Despite the improvement in organ functions, deterioration is usually progressive and sometimes requires renal replacement therapy [2].

Haemodialysis (HD) is the proven method of removing waste products and extra fluid, which build up in the blood when the kidneys are no longer able to function properly. To accomplish HD, it is necessary to have an access to the blood vessels. In patients with ECMO, the classical access can be achieved temporarily by placing a specific double-way venous catheter in one of the large veins in the neck or groin to enable dialysis. Rubin et al had modified the classical HD pathway with connecting a circuit to the ECMO directly and reported that 75% of their patients were conducted a temporary HD or haemofiltration without a delay. Furthermore, they found that the presence of renal impairment was an independent predictor of mortality in patients with heart failure [3].

In this study, we present a technique by using a tool "screw compressor clamp" that provides HD in patients with ECMO. This tool allows performing HD via ECMO lines without a need of access to blood vessels with double-way venous catheter.

Material and Methods

From May 2013 to September 2017, 43 adult patients with ECMO due to end-stage heart failure that required renal replacement treatment with HD were included in this study. Cannulation for ECMO was established through the femoral vessels directly or percutaneously in the right groin. In all patients HD was performed through ECMO circuits and access to blood vessels with specific venous catheter was not necessary. Creatinine, blood urea nitrogen, pH, base deficit, lactate dehydrogenase (LDH) values were evaluated pre and post-HD. Rate of HD, HD duration and ultrafiltration rates were also analyzed (Table 1). Hemofiltration/HD techniques were used to remove fluid and waste products from the blood and to correct electrolyte imbalances, as well as acid-base imbalances. The study was approved by the local research ethics committee.

Technique

The inflow circuit from the dialysis machine (Fresenius Medical Care, Bad Homburg Germany) is connected to the outlet of the oxygenator of ECMO (Circuit ECMO type Reims, DataStream pump, Medos, Xenios AG, Heilbronn, Germany), and the outflow circuit is connected to the venous line of ECMO using two 3-way taps (Figure 1). Therefore, two independent extracorporeal circuits, ECMO and HD, are associated with the use of an external dialysis machine. The pressure in the venous line of ECMO is negative, generating suction with a risk of gas embolism. Between the pump and the oxygenator (arterial line of the ECMO), the pressure is the highest due to the constitutive resistance of the oxygenator. This pressure in the arterial line allows an optimal inflow for HD. Since the pressure is low in the venous line, there is no resistance in the outflow of dialysis machine; drop-off pressure alarm would soon stop HD, therefore, we use Screw Compressor Clamp (Swinging Jaw Clamp, Humboldt Mfg. Co., IL, USA) to increase the pressure on returning line of HD to the venous ECMO line without placing venous dialysis catheter. Consequently, this technique prevents the alarm and provides successful dialysis and ultrafiltration.

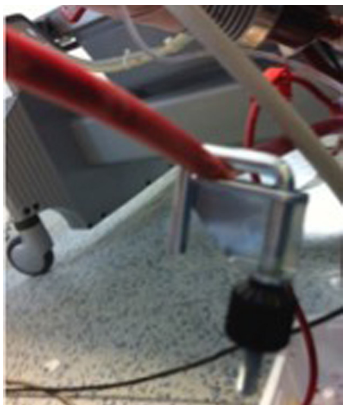

Figure 1: Venous line of extracorporeal membrane oxygenation with Screw Compressor Clamp

This tubing clamp is safe, simple, strong and it can be used on thin or heavy-wall tubing. The clamp is made of plated steel, incorporated a large aluminum and rigid plastic knurled adjusting nut (Figure 2). Substantially, this simple tool is a clamp on a screw, allowing us to squeeze and de-squeeze to set the optimal line pressure.

Figure 2: Screw Compressor Clamp, Swinging Jaw Clamp

Anticoagulation

Anticoagulation was initiated just before the ECMO cannulation procedure with a 50- 100 U/Kg bolus of unfractionated heparin, subsequently continuous unfractionated heparin infusion that targets an activated partial thromboplastin time approximately 1.5 times the normal rate was administered. Therefore, the HD circuit does not require additional anticoagulation.

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation (SD), or median values. Categorical variables were expressed as numbers and percentages. Pre/post-operative variables were compared using "chi-square test" for categorical variables. SPSS pocket program, version 14.0 was used for statistical analysis. A p value < 0.05 was accepted as significant.

Results

Mean age was 36.5±11,2(19-56) years. Thirty-one (72%) patients were male. Indications of ECMO support were 60% dilated cardiomyopathy, 9% restrictive cardiomyopathy, 11% ischemic cardiomyopathy, 10% acute rejection after heart transplant, 10% right ventricular failure after left ventricular assist device implantation. Patient characteristics are shown in Table 1.

Table1. Patients' characteristics

	n:43
Gender	
Female	12 (28%)
Male	31 (72%)
Age (year)	36.5 ± 11, 2 (19-56)
Height (cm)	170 ± 8,2 (149-185)
Weight (Kg)	70,1 ± 13 (46-97)
BSA (m2)	1,8 ± 0,1 (1,5-2,2)
BMI (Kg/m2)	24,1 ± 3,9 (17-30)
Indications of ECMO support	
Dilated Cardiomyopathy	26 (60%)
Restrictive Cardiomyopathy	4 (9%)
Ischemic Cardiomyopathy	5 (11%)
Rejection after Heart Transplant	4 (10%)
RVF after LVAD implantation	4 (10%)
PABP (mmHg)	
Systolic Pressure	47,4 ± 13,2 (22-77)
Diastolic Pressure	26,9 ± 10,6 (10-50)
Mean Pressure	25 ± 7,9 (13-45)
PVR (Wood units)	2,8 ± 1,1 (1-5)
TPG (mmHg)	6,6 ± 3,6 (2-15)
CO (L/min)	2,6 ± 0,8 (1,3-4,3)
CI (L/min/m2)	1,5 ± 0,4 (1-2,7)

BSA: Body surface area, BMI: body mass index, ECMO: Extracorporeal membrane oxygenation, RVF: Right ventricular failure, LVAD: left ventricular assist device, PABP: Pulmonary artery blood pressure, PVR: Pulmonary vascular resistance, TPG: transpulmonary pressure gradient, CO: Cardiac output, CI: Cardiac index

HD was successfully performed in all patients, creatinine, blood urea nitrogen, pH, base deficit values were decreased to the desired levels after HD (Mean blood urea nitrogen was 216,8±51,2 (151-294) mg/dl in pre-HD, 128±29,5(83-172) mg/dl in post-HD). The difference in Pre-HD and post-HD parameters (creatinine, blood urea nitrogen, pH, base deficit) was statistically significant (p<0.05). The rate and duration of HD were 8,2±6,9 (2-22) times and 3,4 ± 0,5 (3-4) hours respectively. The amount of ultrafiltration was 2800±447,2 (2000-3000) ml. LDH values were also compared (pre and post-HD values were 483±239.1 (134-840) and 502±245 (221-898) U/L, respectively). There was a slight increase in LDH values after HD, however the difference was not statistically significant (p=0.446). The results are summarized in Table 2. Average systolic arterial pressure was 74±10,5(50-85) mmHg. In ordinary circumstances, it is not possible to perform HD at low mean arterial pressures; however with this technique, HD is not affected by mean arterial pressure and the dialysis machine can operate efficiently (Figure 3). No bleeding or infection due to this technique was found and no other related complications due to hemodialysis were observed.

Table 2: Parameters of Pre-HD and Post –HD

	pre-HD	post-HD	P value
Creatinine (mg/dl)	3,5 ± 1,08 (2,2-4,9)	2,2 ± 0,75 (1,26-3,67)	.001
Blood urea nitrogen (mg/dl)	216,8±51,2 (151-294)	128 ± 29,5 (83-172)	.001
pH	7,36 ± 0,03 (7,3-7,42)	7,42 ± 0,02 (7,38-7,45)	.001
Base deficit	6 ± 2,8 (-6,16-(-8))	2,25 ± 2,2 < (-4) - 3 <	.001
Rate of HD (time)		8,2± 6,9 (2-22)	
HD duration (hour)		3,4 ± 0,5 (3-4)	
Ultrafiltration (UF) (mL)		2800 ± 447,2 (2000-3000)	
Lactate dehydrogenase (LDH) (U/L)	483 ±239.1(134-840)	502±245(221-898)	.446

HD: hemodialysis

Figure 3: Hemodialysis with hypotension

Discussion

Renal dysfunction (RD) and fluid overload are frequent in patients with chronic congestive heart failure [4]. Before the need of ECMO, critically ill patients with heart failure are at high risk of acute RD due to their condition such as sepsis, ischemia, respiratory failure, decompensated cardiac failure, vasopressor requirements and prevalent use of nephrotoxic medication [5]. Unfortunately, in these patients. need for renal replacement therapy (RRT) after ECMO administration and mortality are increased. Lin et al. reported that adults with acute RD had a 78% mortality compared with 20% in non-acute RD patients [6]. Several renal replacement therapy (RRT) techniques such as peritoneal dialysis, intermittent HD, and continuous RRT (CRRT) are available to support ECMO patients with acute RD and/or fluid overload (FO). Each has its own advantages and disadvantages [7, 8, 9]. Patient factors, treatment goals, and center experience play a role in according to the selected RRT. The simplest way to perform HD is through venous access independent from the ECMO circuit. The most frequent venous accesses used are the internal jugular and subclavian veins. The femoral vein is less frequently chosen, due to the infection risk, and the potential risk of thrombosis in the neighborhood of the ECMO cannula. Additionally, if the patient does not undergo previous cannulation with a central venous catheter, new anticoagulation that is required would increase the risk of bleeding, at the same time the catheter drainage would be insufficient and lead to unsuccessful HD [10, 11]. RRT can also be performed by connecting the dialysis circuit to the ECMO circulation. The two most common methods are; the use of an in-line hemofilter or a traditional device connected to the extracorporeal circuit [12]. However, combining two independent extracorporeal circuits may cause several technical problems, most often associated with the dialysis machine's inlet and outlet pressure alarms [11]. It is possible to connect a dialysis machine to the venous line of the ECMO circuit before the pump, which drives the blood from the ECMO circuit into the dialysis machine. After blood purification, the blood is returned to the ECMO circuit before the ECMO pump. Reconnection of the circuit that contains blood returning from the dialysis machine should be prior to the oxygenator in order to trap the air/clots before returning of patient's bloodstream; additionally, venous admixture has also been avoided due to the shunting in the circuit [10]. The pressure in the arterial line of the ECMO is high according to the blood acceleration by the pump and the arterial resistance of the patient. The inflow catheter of the HD is connected to the venous line and the outflow catheter is connected to the arterial line of ECMO. Although this model is quite easy and "logical", HD is not possible due to permanent high-pressure alarm. Rubin et al [3] reported that the pressure in the venous line was null or negative, generating suction with a risk of gas embolism. Venous pressure was frequently negative during hypovolemia and blood flow rate is the main determinant. In our experience, there was no resistance in the outflow catheter of dialysis machine due to low pressure in the venous line of ECMO; as a result, HD was not possible due to drop-off pressure alarm. We used a Screw Compressor Clamp to increase the pressure on returning line (from HD to the venous ECMO line); consequently, this novel technique provides to stop the alarm and allows to performHD/ultrafiltration possible. In this study, the optimal pressure was achieved by application of this instrument. Maximum care must be taken during the connection of the lines of ECMO and dialysis machine. Simons et al connect the inflow of the dialysis machine to the outlet of the oxygenator, and the outflow circuit that contained returning washed blood was connected to the oxygenator inlet. In their setup, all connections between the ECMO and the dialysis circuits were under positive pressure [13]. They reported that this situation prevented the air from being sucked into the circuit in case of connection failure, therefore, the risk of micro-emboli was reduced. Contrary to Simons' et al. technique in this study, relatively long dialysis lines connected to the cannula as used by Rubin et al was required [3]. Additional attention during patient manipulation to prevent luer connector disconnection or cannula displacement was necessary.

The other disadvantage of combining two independent extracorporeal circuits is hemolysis. Hemolysis could be a specific complication of ECMO, HD or combination of ECMO and HD, with erythrocyte fragmentation caused by the combination of shear stress, positive pressure, wall impact forces and properties of nonendothelialized surfaces [14]. Despite the presence of hemolysis in patients with ECMO that needed HD, the recovery of renal functions seems to be satisfactory. In the absence of primary renal disease, chronic renal failure did not occur in patients with ECMO and these patients weretreated concomitantly with RRT [14, 15, 16]. In our study, there was a slight increase in LDH values after HD however, the difference was not significant.

Study Limitations

The major limitation of this study is its' non-randomized design with a relatively small number of patients. This is also a single center experience; therefore, outcome interpretation is limited by institutional bias.

Conclusion

This technique is a simple, safe and feasible method to perform a successful filtration and dialysis using ECMO lines without placing a specific venous catheter. Screw Compressor Clamp increased the pressure on returning line of HD to the venous extracorporeal membrane oxygenation line; and made dialysis and ultrafiltration possible even in low blood pressure. Further large investigations are needed to demonstrate the validity of this technique.

Declaration of conflict of interest

The authors received no financial support for the research and/or authorship of this article. There is no conflict of interest

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