Learning Curve for Temporary Hemodialysis Catheter Placement

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ABSTRACT

Background. Training is essential for the safe and uncomplicated placement of hemodialysis catheters. This study explores the learning curve of this procedure.

Methods. In this prospective study, 60 patients who needed emergency hemodialysis without vascular access were included. All catheters were placed under ultrasound guidance. One nephrologist was included in each two groups, one to be consisted of a junior, and one to be consisted of a senior. Learning curves were created using the cumulative total methodology and receiver operating characteristic curve analyses.

Results. The patients' mean age was 67.92 ± 14.23 years. The mean catheter insertion time of the senior nephrologist was significantly shorter than that of the junior. According to cumulative total analysis, the junior group's maximum learning point overlaps with patient 22. When the confidence intervals of the study durations of both groups were examined, they overlapped in the 95% confidence interval starting from the 19th patient. When the mean catheter insertion time of the senior and the mean of the last 12 patients of the junior were compared, there was no significant difference between them (F = 15.827, P = .092). The receiver operating characteristic curve analysis showed a cutoff value of 320 seconds for the junior group compared with the senior group, indicating an overlap in case 22 for the junior nephrologist.

Conclusion. This study suggests that 22 catheter insertions under the supervision of a senior nephrologist are needed to complete the learning curve for a junior nephrologist. If the number of nephrologists at the center is limited, safe catheter insertion may be allowed after 19 insertions.

THE number of patients with chronic kidney disease and acute kidney injury (AKI) has been increasing worldwide [1,2]. In particular, most patients require hemodialysis (HD) in the emergency setting [3]. In addition, the need for emergency HD increases during natural disasters such as catastrophic earthquakes characterized by landslides and debris flow [4].

For HD, vascular access is established by inserting a non-tunneled (temporary) HD catheter via the jugular or femoral route. This type of catheter is placed by vascular surgeons, emergency medicine specialists, intensive care specialists, and interventional nephrologists. Although it is a simple procedure associated with mild complications such as bleeding and hematoma, it may cause serious complications leading to death [5–7].

In interventional nephrology, transferring the skills of the specialist via a master-apprenticeship relationship is of utmost importance. A junior interventional nephrologist is expected to gain skills and experience after an adequate number of interventions under the supervision of a senior specialist. We planned this study because we saw that such a study had not been done before among nephrologists on this subject. We aimed to compare the results of HD catheter insertion by senior vs junior nephrologists and to establish the learning curve of this technique on nephrologists using a cumulative sum (CUSUM)

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chart, which has been widely used to evaluate the learning curves of surgical techniques since the 1970s [8,9].

MATERIALS AND METHODS

Study Design and Study Population

This single-center, prospective study was conducted at the Department of Nephrology of a tertiary care center between June 1, 2021, and December 30, 2021. Before the study, all patients were informed about the diagnostic and therapeutic procedures, and written informed consent was obtained. The institutional ethics committee approved the study protocol (Date: 10.03.2021; No: 2021/0011). The study was conducted per the principles of the Declaration of Helsinki.

A 48-year-old experienced nephrologist with experience with >1000 catheter placements was selected for this study. A 34-year-old nephrology fellow who completed a 1-year training period as a junior nephrologist was included. A total of 60 patients aged >18 years who required emergency HD without vascular access were included. Patients with a previous history of ipsilateral catheter insertion and those having vascular variations, as evidenced by preoperative ultrasonography (USG), were excluded from the study. All catheters were inserted under the guidance of USG. Before the catheter insertion, all patients underwent complete blood count analysis, activated partial thromboplastin time, prothrombin time, international normalized ratio (INR), and viral serologic tests (hepatitis B virus, hepatitis C virus, HIV). Patients with an INR >2.0 and platelet count of <50,000 × 10^6/L were excluded. Vascular access was first attempted via the right internal jugular vein (IJV); the left IJV and femoral vein were used if the access via the right IJV failed. Data including age, sex, body weight, height, body mass index (BMI), blood pressure, and comorbidities were retrospectively analyzed.

Procedural Technique

All procedures were performed using prilocaine under local anesthesia. The catheter insertion site was cleaned in accordance with the aseptic and antiseptic principles and covered with a sterile drape. The procedural initiation time was defined as when the needle tip was first inserted for local anesthesia. In contrast, the procedure completion time was defined as when the final suture was placed. The procedural time for each patient was recorded in seconds. During the procedure, venipunctures and inadvertent arterial punctures, atrioventricular dysrhythmias, procedural time, and the success and failure rate of the procedure were noted. After the procedure, all patients were followed for bleeding, hematoma, pneumothorax, air embolism, pericardial tamponade, cardiovascular perforations, and catheter malposition. All patients who underwent jugular vein catheterization underwent chest radiographs and were evaluated for catheter malposition and pneumothorax.

A senior nephrologist and a junior nephrologist inserted temporary catheters for the first 20 patients. The catheters of the next 20 patients were inserted by a junior nephrologist under senior supervision. Catheters after the first 40 patients continued to be inserted by an old and a junior, respectively. A 12-Fr, 20-cm double-lumen HD catheter was used for femoral access, whereas a 12-Fr, 15-cm double-lumen HD catheter was used for jugular access.

CUSUM Analysis

The learning curve is a mathematical modeling of the learning process. The CUSUM methodology is often used to evaluate individual skills and performance in surgical procedures. The present study used the CUSUM analysis to assess the learning curve quantitatively. The CUSUM is the running total of differences between the individual data points and the mean of all data points. In this study, all patients were designated a number based on the catheter insertion date. The catheter insertion duration for each patient (*xi*) and the average duration of catheter insertion for the overall study population (μ) were defined. The CUSUM duration, defined as the cumulative sum value of the procedure time ($CUSUM_{OTn}$), was calculated using the following formula [9]:

$$CUSUM_{OTn} = \sum_{i=0}^{n} xi - \mu$$

Statistical Analysis

Statistical analysis was performed using the SPSS, version 20.0 software (IBM SPSS, Inc, Armonk, NY, United States). Descriptive data were expressed in mean ± SD or number and frequency. The Student *t* test was used to compare quantitative data between the 2 groups, and the χ^2 test was used to analyze categorical variables. The Pearson correlation coefficient was used to analyze the relations of quantitative variables. The CUSUM analysis was performed for the learning curve analysis. The receiver operating characteristic (ROC) curve was carried out to determine the cutoff values of the learning process with the area under the curve (AUC) values. The Mann-Whitney *U* test was performed to calculate the CIs of the catheter insertion duration. A *P* value of < .05 was considered statistically significant.

RESULTS

A total of 60 patients were included in the study, and the patients were divided into 2 equal groups according to the interventionist (senior nephrologist, n = 30; junior nephrologist, n = 30). Forty-one (68.3%) of the patients were male. There was no significant difference in the sex of the senior group, whereas male predominance was found in the junior group (83.3%) (^{2} = 6.2; $P = .012$). The overall mean age was 67.92 ± 14.23 years, indicating no significant difference between the groups ($t = -0.79$; $P = .435$) (Table 1).

The mean systolic and diastolic blood pressures were 128.80 ± 22.37 mm Hg and 73.03 ± 12.09 mm Hg, indicating statistically significantly higher pressures in the junior group than in the senior group ($t = -2{,}32$, $P = .024$; $t = -2.13$, $P = .037$). The mean BMI was 27.37 ± 5.21 kg/m^2 and was significantly higher in the senior group than in the junior group (30.10 ± 4.17 kg/m^2 vs 24.65 ± 4.74 kg/m^2, respectively; $t = 4.72$, $P < .001$). Hypertension was seen in 68.3% (n = 41), diabetes in 36.7% (n = 22), coronary artery disease in 15% (n = 9), heart failure in 11.7% (n = 7), and chronic obstructive pulmonary disease in 1.7% (n = 1) of the patients (Table 1).

Catheter insertion duration, complications, and drugs used are summarized in Table 2. The mean catheter insertion duration was 292.57 ± 60.8 seconds for the senior nephrologist and 395.07 ± 98.3 seconds for the junior nephrologist, indicating a statistically significant difference ($t = -4.86$; $P < .001$). According to the CUSUM analysis, the junior group's maximum learning point overlaps with patient 22 (Fig 1). When the CIs of the study durations of both groups

Table 1. Demographic and Clinical Characteristics of Patients

			Female	Male	Total	χ^2	*P* Value
Sex	Total	n	19	41	60		
		%	31.7	68.3	100.0		
	Senior	n	14	16	30	6.239	.012
		%	46.7	53.3	100.0		
	Junior	n	5	25	30		
		%	16.7	83.3	100.0		
Age, y	Senior		n	Mean	SD	*t* test	*P* Value
			30	66.47	11.96	−0.787	.435
	Junior		30	69.37	16.26		
	Total		60	67.92	14.23		
BMI, kg/m^2			n	mean	Sd	*t* test	*P* Value
	Senior		30	30.1	4.17	4.724	< .001
	Junior		30	24.65	4.74		
	Total		60	27.37	5.21		
Systolic blood pressure, mm Hg			n	mean	Sd	*t* test	*P* Value
	Senior		30	122,33	21,43	−2.320	.024
	Junior		30	135,27	21,75		
	Total		60	128,80	22,37		
Diastolic blood pressure, mm Hg			n	Mean	SD	*t* test	*P* Value
	Senior		30	69.80	10.51	−2.132	.037
	Junior		30	76.27	12.87		
	Total		60	73.03	12.09		
Hypertension			n	%		χ^2	*P* Value
	Senior		24	80.0		1.832	.176
	Junior		17	56.7			
	Total		41	68.3			
Diabetes			n	%		χ^2	*P* Value
	Senior		12	40.0		0.287	.592
	Junior		10	33.3			
	Total		22	36.7			

BMI, body mass index.

were examined, it was observed that they overlapped in the 95% CI starting from the 19th patient (P[284.5 ≤ junior ≤ 419.7 seconds]; P[233.4 ≤ all of the senior group ≤ 306.4 seconds] 95% CI).

When the average of the entire catheter insertion time of the senior nephrologist and the last 12 patients of the junior nephrologist were compared, there was no significant difference between them ($F = 15.827$, $P = .092$). When ROC curve analysis was performed by comparing the senior and junior nephrologist groups, the cutoff value for the junior group was found to be 320.0 seconds. This value coincided with the 22nd case in the junior group (AUC [95% CI]: 0.827 [0.721-0.933], $P <$ .001) (Fig 2).

Inadvertent arterial puncture occurred in 1 patient in the senior group and once in 2 patients in the junior group, indicating no significant difference between the groups ($t = -0.58$; $P = .561$). Although 29 patients underwent venipuncture once and 1 patient underwent venipuncture twice in the senior group, venipuncture was performed in 26 patients once and in 4 patients twice in the junior group. However, it did not reach statistical significance ($t = -1.40$; $P = .168$). One patient in each group had a self-limiting hematoma. None of the patients in either group had additional complications.

Complete blood count analysis and biochemical test results are shown in Table 3. The mean serum creatinine level was

Table 2. Catheter Insertion Duration, Complications, and Drugs Used

Group		N	Mean	SD	*t**	*P* Value*
Catheter insertion duration, s	Senior	30	292.57	60.80	−4.86	< .001
	Junior	30	395.07	98.28		
Right IJV	Senior	20	66.7%			
	Junior	28	93.3%			
Left IJV	Senior	7	23.3%			
	Junior	1	3.3%			
Right FV	Senior	2	6.7%			
	Junior	1	3.3%			
Left FV	Senior	1	3.3%			
	Junior	0	0%			
Arterial puncture, n	Senior	1	0.03	0.18	−0.58	.561
	Junior	2	0.07	0.25		
Venipuncture, n	Senior	31	1.03	0.18	−1.40	.168
	Junior	34	1.13	0.35		
Hematoma, n	Senior	1	3.3%			1.000†
	Junior	1	3.3%			
Warfarin use, n	Senior	4	13.3%			.112†
	Junior	0	0%			
ASA use, n	Senior	6	20%		0.480†	.488†
	Junior	4	13.3%			
Antihypertensive use, n	Senior	24	80.0%		8.531‡	.003‡
	Junior	13	43.3%			

ASA, acetylsalicylic acid; FV, femoral vein; IJV, internal jugular vein.
* Independent samples *t* test, *t* test for equality of means.
† Fisher exact test.
‡ χ^2 test.

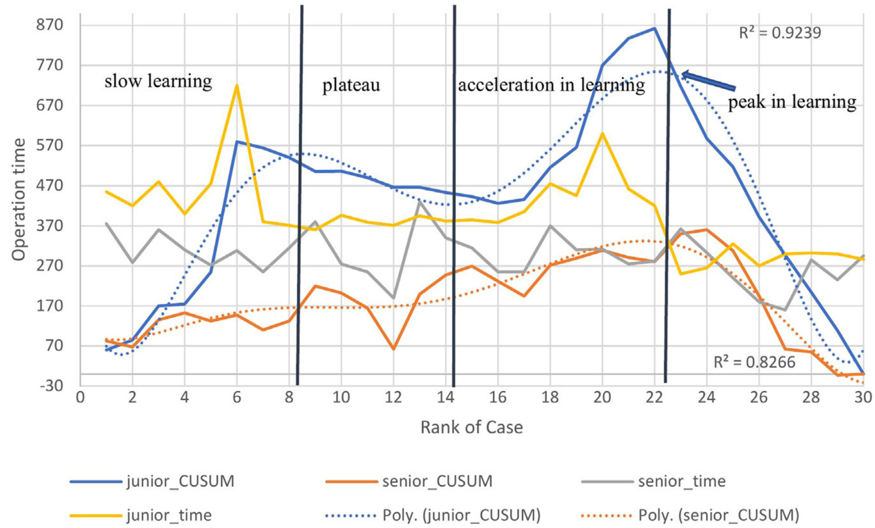

Fig 1. Analysis of the learning curve with cumulative sum method. CUSUM, cumulative sum.

5.72 ± 2.4 mg/dL. The mean estimated glomerular filtration rate was 10.91 ± 7.8 mL/min. The mean sodium level was 134.1 ± 5.7 mEq/L, and the mean potassium level was 4.74 ± 1.1 mEq/L. The mean prothrombin time was 16.54 ± 4.7 seconds, and the mean INR was 1.22 ± 0.27. There was no significant difference between the groups regarding serum creatinine level, estimated glomerular filtration rate, sodium, potassium, and INR ($P > .05$).

DISCUSSION

In the present study, we compared the results of HD catheter insertion by senior vs junior nephrologists, and we attempted to establish the learning curve of this technique on nephrologists using the CUSUM analysis. To the best of our knowledge, this is the first study in the literature to investigate the learning curve of inserting a temporary HD catheter among nephrologists. In this study, the learning curve was given as a graphical representation of the relationship between the catheter insertion skills of the nephrologist and the number of cases using the CUSUM method. Pediatric heart surgeons first used this method, and it is still used to assess surgeons' surgical performance and outcomes [10,11].

In the current study, according to the CUSUM analysis, the maximum learning point of the young group coincides with the 22nd patient (Fig 1). In addition, when the CIs of the study durations of both groups were examined, they overlapped in 95 CI starting from the 19th patient (P[284.5 ≤ junior ≤ 419.7 seconds]; P[233.4 ≤ all of senior ≤ 306.4 seconds] 95% CI). There was a significant difference between the mean catheter times of the first 22 patients of the junior group and the mean times of all catheters of the senior group (423.7 ± 83.5 seconds, P[382.2 < junior-18 < 465.3]; 292.6 seconds, P[269.9 < senior-all < 315.3], 95% CI, $P < .001$).

The mean catheter insertion duration was 352.08 ± 106.416 seconds for the last 12 patients in the junior group, indicating no significant difference between the junior and senior nephrologists

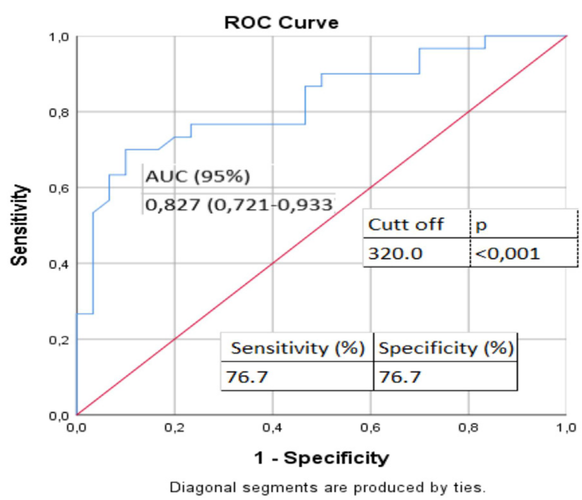

Fig 2. Analysis of the learning curve with receiver operating characteristic curve. AUC, area under the curve; ROC, receiver operating characteristic.

($F = 7.09$, $t = -1.8$, $P = .09$). This finding indicates similar catheter insertion time for both senior and junior nephrologists.

The ROC curve analysis allows for comparing the diagnostic performance of 2 or more diagnostic or laboratory tests, assessing the quality of the laboratory test results, evaluating the operator's development process, and comparing the different operators' effectiveness [12]. In the present study, the ROC curve analysis showed a cutoff value of 320 seconds for the junior group compared with the senior group, indicating an overlap in case 22 for the junior nephrologist (AUC, 0.827; $P < .001$) (Fig 2). According to CUSUM and ROC curve analyses, these findings suggest that a junior nephrologist can gain skills and competence in catheter insertion by case 22. In addition, a junior nephrologist can achieve sufficient competence after case 19, as evidenced by the 95% CI (Mann-Whitney U test) and the mean catheter insertion duration for the last 12 patients. Taken together, junior nephrologists can safely insert an HD catheter after case 22 if the number of

Table 3. Complete Blood Count Analysis and Biochemical Test Results

Group		n	Mean	SD	*t*	*P* Value
Hb, g/dL	Senior	30	9.82	2.26	0.138	.891
	Junior	30	9.75	2.10		
Hct, %	Senior	30	30.17	7.24	0.922	.360
	Junior	30	28.65	5.36		
MCV, fL	Senior	30	86.14	9.48	−0.988	.327
	Junior	30	88.12	5.46		
WBC, $\times 10^6$/L	Senior	30	9322.00	4880.05	−0.446	.657
	Junior	30	9986.00	6535.08		
Lymphocyte, $\times 10^6$/L	Senior	30	1196.63	765.88	0.499	.619
	Junior	30	1106.00	633.83		
PNL, $\times 10^6$/L	Senior	30	7758.33	4845.86	−0.086	.931
	Junior	30	7885.00	6393.50		
PLT, $\times 10^9$/L	Senior	30	182.20	101.81	−0.831	.409
	Junior	30	205.13	111.70		
Urea, mg/dL	Senior	30	158.03	71.28	−0.130	.897
	Junior	30	160.33	65.17		
Creatinine, mg/dL	Senior	30	5.54	2.55	−0.605	.547
	Junior	30	5.91	2.29		
Sodium, mEq/L	Senior	30	133.40	5.47	−0.950	.346
	Junior	30	134.80	5.93		
eGFR, mL/min	Senior	30	11.77	9.03	0.853	.397
	Junior	30	10.05	6.38		
Potassium, mEq/L	Senior	30	4.80	0.91	0.378	.707
	Junior	30	4.69	1.25		
Calcium, mg/dL	Senior	30	8.72	0.93	1.871	.066
	Junior	30	8.34	0.62		
Albumin, g/dL	Senior	30	3.39	0.57	2.106	.040
	Junior	30	3.06	0.65		
Fasting blood glucose, mg/dL	Senior	30	134.17	68.45	2.114	.039
	Junior	30	103.13	42.17		
PT, s	Senior	30	17.44	5.77	1.496	.142
	Junior	30	15.64	3.16		
INR	Senior	30	1.27	0.33	1.225	.227
	Junior	30	1.18	0.19		
aPTT, s	Senior	30	34.17	12.00	−0.684	.497
	Junior	30	37.58	24.46		

aPTT, activated partial thromboplastin time; eGFR, estimated glomerular filtration rate; Hb, hemoglobin; Hct, hematocrit; INR, international normalized ratio; MCV, mean corpuscular volume; PLT, platelet; PNL, polymorphonuclear leukocyte; PT, prothrombin time; WBC, white blood cell.

A p value of < 0.05 was considered statistically significant.

nephrology specialists is adequate in the clinic. Otherwise (ie, in case of a limited number of specialists in the clinic), catheter insertion can be allowed after case 19.

The estimated global prevalence of chronic kidney disease is 13.4%, and it is 1 of the major public health issues worldwide [1]. About 4.90 to 7.08 million patients with end-stage renal disease require renal replacement therapy (RRT) [1]. Acute kidney injury is 1 of the most common and serious complications of hospitalized patients, particularly those requiring intensive care [13]. There is no established medical treatment for AKI yet; thus, RRT is considered the gold-standard support in managing severe AKI and end-stage renal disease [14]. Hemodialysis is the most common RRT worldwide [15]. According to the 2019 Turkish Society of Nephrology registry report, HD is the most common type of RRT in Turkey (74.8%), followed by renal transplantation (21.2%) and peritoneal dialysis (9%) [16].

The placement of non-tunneled (temporary) dialysis catheters is 1 of the basic procedures in nephrology practice. Although emergency dialysis can be lifesaving, fatal complications can be encountered when inserting the non-tunneled (temporary) dialysis catheters [5,17]. Therefore, nephrologists should gain adequate knowledge and skills in catheter placement [18]. A study by McQuillan et al [19] evaluated the temporary HD catheter placement skills of 20 nephrology fellows with 20 questions. After a simulation-based training of approximately 24 hours, the posttests were repeated with the same questionnaire questions, and the change in their skills was reevaluated. Looking at the pre- and post-tests, they emphasized that the simulator-based training model is an effective method. Similarly, Barsuk et al previously conducted a study using the simulation-based learning skill enhancement model [20]. Our aim in this study was to teach nephrology students to insert a catheter and to increase their skills. We were looking for when a fellow would attain sufficient knowledge and skills. In contrast to other studies that used simulations for the education of the temporary hemodialysis catheter placement skills, we instead focused our study to involve real patients in our educations for catheter placement.

Clark et al found the median number of catheters inserted in the past 6 months to be 5 in a web-based temporary HD catheter placement survey. In the same study, 33% of the trainees stated they were not educated enough [21]. In our study, a senior nephrologist and a junior nephrologist inserted the temporary catheters of the first 20 patients. The catheters of the next 20 patients were inserted by a junior nephrologist under senior supervision. Subsequent catheters continued to be inserted by a senior and a junior, respectively. Inadvertent arterial puncture occurred in 1 patient in the senior group and 2 patients in the junior group. One patient in each group had a self-limiting hematoma without regional pressure. None of the patients in either group had additional complications.

In another study, Bansal et al [22] reported successful vein catheter insertion in all patients under the guidance of USG. Similarly, in our study, the vein catheter insertion success rate was 100% (n = 30) performed by the senior nephrologist, whereas the first attempt success rate was 86.7% when performed by the junior nephrologist (n = 26). The rate of inadvertent arterial puncture was 3.3% (n = 1) in the senior group and 6.7% (n = 2) in the junior group. There was no significant difference in the venipuncture and inadvertent arterial puncture between the senior and junior nephrologists (P = .561 and P = .168, respectively). The HD catheter insertion under the guidance of USG was associated with fewer complications and a higher successful first-attempt cannulation rate.

Nonetheless, there are some limitations to this study. First, there was only 1 junior nephrologist in the junior group. Further studies, including multiple nephrologists with varying degrees of experience, may provide more accurate results for the learning curve. Second, the patients on warfarin treatment were assigned to the senior group, and the patients in the senior group had significantly higher BMI values, indicating heterogeneity of the patient population. Third, the small sample size was another limitation: the training did not start in the simulation center. Finally, the junior nephrologist had no experience in left femoral vein cannulation.

CONCLUSIONS

This study establishes 3 unique steps of the HD catheter insertion learning curve using CUSUM analysis. The study results suggest that 22 catheter insertions under the supervision of a senior nephrologist are needed to complete the learning curve for a junior nephrologist. If the number of nephrologists is limited, a junior nephrologist may be allowed to safely perform catheter placement after 19 insertions. However, further large-scale, prospective studies are needed, including multiple junior nephrologists, to confirm these findings and draw a firm conclusion.

DISCLOSURES

All the authors declare no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

REFERENCES

[1] Lv JC, Zhang LX. Prevalence and disease burden of chronic kidney disease. Adv Exp Med Biol 2019;1165:3–15.

[2] Sawhney S, Fraser SD. Epidemiology of AKI: utilizing large databases to determine the burden of AKI. Adv Chronic Kidney Dis 2017;24:194–204.

[3] Nadim MK, Forni LG, Mehta RL, et al. COVID-19-associated acute kidney injury: consensus report of the 25th Acute Disease Quality Initiative (ADQI) Workgroup. Nat Rev Nephrol 2020;16:747–64.

[4] Sever MS, Erek E, Vanholder R, et al. Treatment modalities and outcome of the renal victims of the Marmara earthquake. Nephron 2002;92:64–71.

[5] Chen IC, Yang SC, Liu KT, Wu YH. Delayed malposition of a double-lumen hemodialysis catheter that caused hemorrhage and hypovolemic shock: a case report. Medicine 2019;98:e14192.

[6] Zahdi O, Lahlou ND, Bhali HE, et al. [Iatrogenic carotid-jugular arterio-venous fistula: a rare complication associated with jugular venous catheterization (a case report)]. Pan African Med J 2020;37:379.

[7] Premuzic V, Katalinic L, Pasalic M, Jurin H. Nonfatal cardiac perforation after central venous catheter insertion. Saudi J Anaesth 2018;12:118–20.

[8] Chaput de Saintonge DM, Vere DW. Why don't doctors use cusums? Lancet 1974;1:120–1.

[9] Park JS, Ahn HK, Na J, et al. Cumulative sum analysis of learning curve for video-assisted mini-laparotomy partial nephrectomy in renal cell carcinoma. Medicine 2019;98:e15367.

[10] Grunkemeier GL, Jin R, Wu Y. Cumulative sum curves and their prediction limits. Ann Thorac Surg 2009;87:361–4.

[11] de Leval MR, François K, Bull C, Brawn W, Spiegelhalter D. Analysis of a cluster of surgical failures. Application to a series of neonatal arterial switch operations. J Thorac Cardiovasc Surg 1994;107:914–23 discussion 923−24.

[12] Carter JV, Pan J, Rai SN, Galandiuk S. ROC-ing along: evaluation and interpretation of receiver operating characteristic curves. Surgery 2016;159:1638–45.

[13] Negi S, Koreeda D, Kobayashi S, et al. Acute kidney injury: epidemiology, outcomes, complications, and therapeutic strategies. Semin Dialysis 2018;31:519–27.

[14] Küllmar M, Zarbock A. [Renal replacement therapy in acute kidney injury: from the indications to cessation]. Der Anaesthesist 2019;68:485–96.

[15] Qarni B, Osman MA, Levin A, et al. Kidney care in low- and middle-income countries. Clin Nephrol 2020;93:21–30.

[16] Seyahi N, Ateş K, Süleymanlar G. Current status of renal replacement therapy in Turkey: a summary of the Turkish Society of Nephrology Registry Report. Turkish J Nephrol 2020;29:6–11.

[17] Kaya C, Burcu Ustun Y, Koksal E, Dursun M. A complication of temporary subclavian vein haemodialysis catheter: vena cava superior injury. Clin Ter 2014;165:e362–4.

[18] Yuan CM, Oliver 3rd JD, Little DJ, et al. Survey of non-tunneled temporary hemodialysis catheter clinical practice and training. J Vasc Access 2019;20:507–15.

[19] McQuillan RF, Clark E, Zahirieh A, et al. Performance of temporary hemodialysis catheter insertion by nephrology fellows and attending nephrologists. Clin J Am Soc Nephrol 2015;10:1767–72.

[20] Barsuk JH, Ahya SN, Cohen ER, McGaghie WC, Wayne DB. Mastery learning of temporary hemodialysis catheter insertion by nephrology fellows using simulation technology and deliberate practice. Am J Kidney Dis 2009;54:70–6.

[21] Clark EG, Schachter ME, Palumbo A, Knoll G, Edwards C. Temporary hemodialysis catheter placement by nephrology fellows: implications for nephrology training. Am J Kidney Di 2013;62:474–80.

[22] Bansal R, Agarwal SK, Tiwari SC, Dash SC. A prospective randomized study to compare ultrasound-guided with nonultrasound-guided double lumen internal jugular catheter insertion as a temporary hemodialysis access. Renal Fail 2005;27:561–4.