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Rectus abdominis muscle thickness as a predictor of peritoneal catheter dysfunction in emergency-start peritoneal dialysis patients

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Abstract. Background: Percutaneous insertion of a peritoneal dialysis catheter (PDc) is an alternative to open surgical techniques, and the anatomical characteristics of the abdominal wall may predict PDc dysfunction. We evaluated the role of rectus abdominis muscle (RAM) thickness as a predictor of PDc dysfunction. Materials and methods: A prospective cohort of emergency-start PD patients (EmPD) who had their first percutaneous PDc insertion were included. PDc failure was defined as the removal of a PDc due to mechanical failure within the first 30 PD fluid exchanges. Clinical variables were recorded. The skin to parietal peritoneum depth and RAM thickness were determined by abdominal ultrasound. Univariate and multivariate logistic regression models were developed to test associations between clinical parameters and PDc dysfunction. Results: Over 6 months, 119 patients underwent PDc insertion; 73 (61.3%) were males, with a mean age of 46.0 ± 17.8 years. The mean skin-to-peritoneum depth was 2.5 ± 1.0 cm, the RAM thickness was 0.91 ± 0.3 cm, and catheter implantation was successful in 116 (97.4%) patients. Insertion failed in 3 (2.5%) cases, and 30 (25.8%) patients presented with catheter dysfunction. Univariate analysis indicated that RAM thickness ≥ 1.0 cm, skin-to-peritoneum depth > 2.88 cm, abdominal waist > 92.5 cm, and skin-to-RAM fascia distance > 2.3 cm were associated with PDc dysfunction; in multivariate logistic regression analysis, only greater RAM thickness remained a significant predictor (OR 1.6, 95% CI 1.38 – 1.88, p < 0.001). Conclusion: In EmPD patients, RAM thickness is associated with PDc dysfunction and could aid in identifying patients at risk for PDc dysfunction in emergency settings. Additional adequately powered studies are needed to confirm our findings.

Introduction

Peritoneal dialysis (PD) is the most frequent dialysis modality used in Mexico [1, 2]. A growing number of centers around the world have increased the use of PD due to its simplicity and considerably low costs [3, 4, 5]. Compared to an elective start of PD, emergency PD (EmPD) has higher early complication rates and comparable long-term technique survival [6]. PD catheter (PDc) dysfunction is an important cause of technique failure and increases the risk of PD failure, particularly within the first 3 months of therapy [7, 8]. Strategies to prevent early PDc dysfunction include appropriate catheter selection, optimal surgical techniques, and good postoperative care [9], but only a few studies have analyzed the anatomical characteristics of the abdominal wall as a predictor of PDc dysfunction [10, 11]. In this context, the thickness of the rectus abdominis muscle (RAM) could be associated with a higher risk of PDc dysfunction. We investigated the performance of RAM thickness to predict PDc dysfunction in a cohort that commenced treatment in our center in Jalisco, Mexico.

Materials and methods

We conducted a single-center, prospective cohort study at the Hospital Civil de Guadalajara Fray Antonio Alcalde, Jalisco, Mexico, a tertiary-care center in western

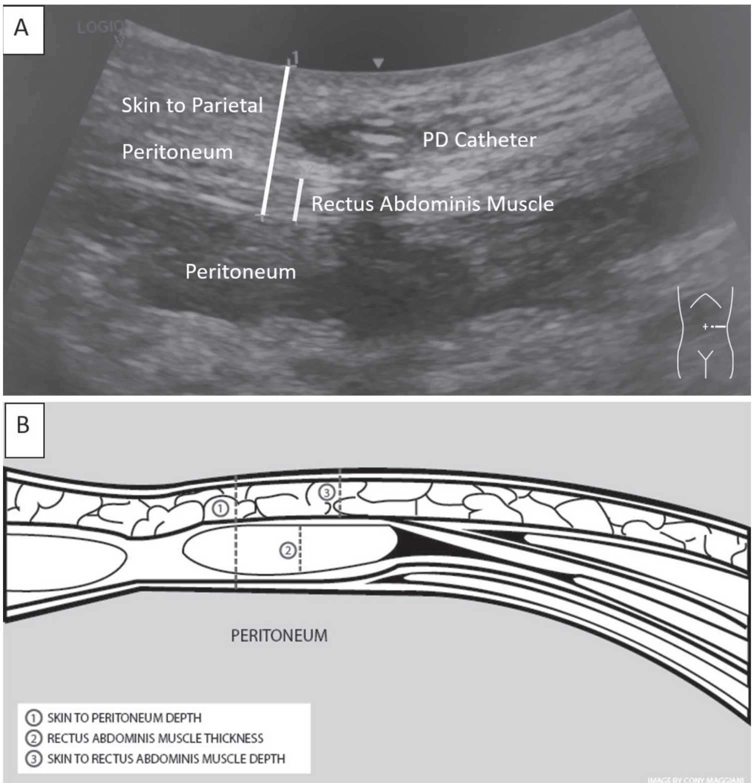

Figure 1. A: Ultrasound image of the abdominal wall after insertion of the catheter; B: schematic representation of the abdominal wall.

Mexico providing health care to patients without medical insurance. End-stage renal disease (ESRD) patients ≥ 18 years old who had their first percutaneous PDc insertion and initiated EmPD between March 2018 and October 2018 were eligible for participation. A medical history was obtained, including the presence of diabetes, previous abdominal surgery, cause of ESRD, body mass index (BMI), waist measurement, obesity, and central obesity. Ultrasound equipment (GE LOGIQ V2, GE Healthcare, Boston, MA, USA) with a broad-spectrum convex transducer was used to assess the distance between the skin and the parietal peritoneum as well as the RAM thickness. All PD catheters, straight or coiled, were inserted by nephrology fellows. The primary binary outcome was PDc failure, defined as the removal of a catheter due to mechanical dysfunction within the first 30 PD fluid exchanges. The primary hypothesis focused on the association between RAM thickness and PDc dysfunction. Additionally, associations between PDc dysfunction and central obesity, BMI, and skin to parietal peritoneum depth were evaluated. Serum creatinine (Scr) was used to estimate the glomerular filtration rate (eGFR) using the CKD-EPI study equation [12]. The study was approved by the Hospital Civil de Guadalajara Fray Antonio Alcalde Institutional Review Board. The protocol followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [13].

Peritoneal dialysis catheter insertion technique and ultrasound measurement description

After obtaining informed consent and previous bowel preparation, patients proceeded to empty the urinary bladder; a vertical paraumbilical incision was made under local anesthesia, followed by dissection of subcutaneous tissue and blunt dissection of the RAM fascia, splitting the muscle fibers with a straight Kelly clamp. Subsequently, a dilator was advanced with a stylet into the abdominal cavity, proceeding to perforate the parietal peritoneum and insert the PDc. All the catheters were placed perpendicular to the skin and RAM (90°). A small variation could be present but minimal. Finally, the internal cuff was placed within the rectus muscle, and a suture was placed around the catheter in the rectus muscle. Dialysate fluid infusion and drainage flow were then tested; when adequate (10-minute infusion and 20-minute drainage), the PDc was tunneled cephalically, placing the external cuff in the subcutaneous tissue 2 cm from the exit site and closing the skin with Vicryl 2-0 and Nylon 2-0. Patients remained supine for 24 hours after PDc insertion. Intravenous cefotaxime (1 g) or ceftriaxone (1 g) were administered prophylactically.

Within the following 6 hours after catheter placement, an abdominal wall ultrasound was performed. Because catheter insertion was performed by different nephrology fellows, who might change the insertion site, it was decided that all measurements be made after the placement of the PDc to evaluate the thickness of the RAM at the exact point of PDc insertion to avoid measurement bias. All metrics were performed by the same nephrologist. The applied pressure to the transducer on the abdominal wall was the minimum required for the entire face of

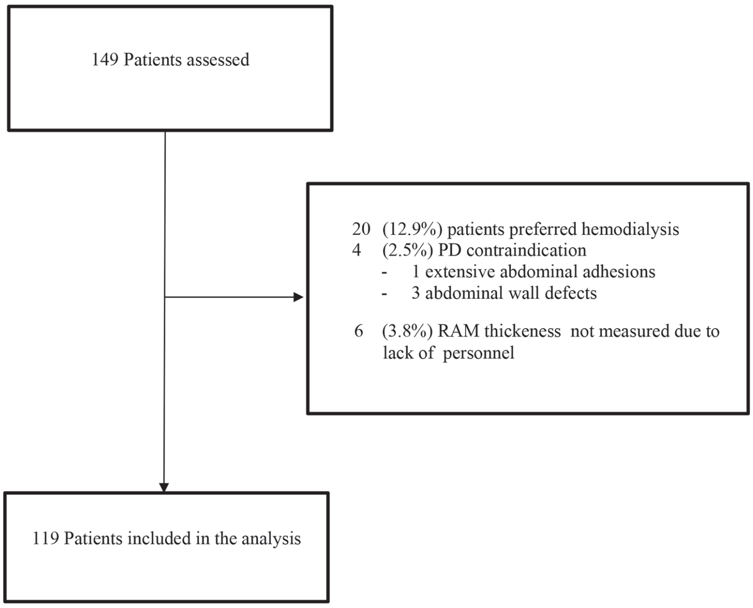

Figure 2. Flow chart of the patients assessed.

the transducer to make contact with the patient's skin. The distance between the skin and the parietal peritoneum and the RAM thickness in centimeters in the sagittal plane were measured at the medial border of the rectus abdominis muscle and at the umbilical level, just above the surgical incision (Figure 1). The measurements were made after the placement of the PDc to evaluate the thickness of the RAM at the exact point of PDc insertion to avoid measurement bias. Patients were followed during the first 30 2L-1.5% dextrose exchanges or until the presentation of PDc dysfunction, whatever occurred first. If the dialysate inflow stopped or significantly slowed, mechanical causes were suspected. After checking that the tubing and catheter were not kinked and that all clamps were open, the catheter was flushed vigorously with 20 mL of heparinized saline. If dysfunction persisted, an abdominal X-ray was taken. If the catheter had migrated, an attempt to reposition the catheter tip into the pelvis was performed with the use of a sterile guidewire inserted into the catheter. In all cases, constipation was treated with oral laxatives or an enema. We did not use tissue plasminogen activator (t-PA) to dissolve any potential clot in any case. No attempt was made to restore catheter function with laparoscopy or disentanglement from the omentum, mesentery, or other intraperitoneal structures. The catheter was removed if any of the above procedures failed.

Statistical analysis

Categorical variables are presented as frequencies, and continuous variables are presented as the mean ± SD. Variables were tested for normal distribution using the Shapiro-Wilk normality test. χ^2-tests and t-tests were used when appropriate. A p-value < 0.05 was considered statistically significant. Univariate and multivariate logistic regression analyses were used to determine clinical parameters (RAM thickness, abdominal waist, BMI, skin to peritoneum depth, skin to RAM fascia depth, previous abdominal surgery, age, serum Hgb, and serum albumin) associated with primary PDc dysfunction. Receiver operating characteristic (ROC) curves were constructed to assess the sensitivity and specificity of the different variable measurements and to compare their ability to diagnose PDc dysfunction. Statistical analysis was performed using MedCalc statistical package version 12.7 (MedCalc Software, Ostend, Belgium).

Results

Between March 1 and October 30, 2018, 149 consecutive patients were evaluated; 20 (12.9%) patients were placed on hemodialysis, 4 (2.5%) had contraindications to PD, and in 6 (3.8%) patients, the RAM thickness was not measured due to the lack of personnel, resulting in 119 patients included in the final analysis (Figure 2).

73 (61.3%) patients were male, with a mean age of 46.0 ± 17.8 years; diabetes was present in 28 (23.5%) patients, and 9 (7.5%) were obese; and 13 (11%) patients had previous abdominal surgery (7 appendectomies (5.8%), 4 cesarean sections (3.3%), 1 hysterectomy (0.8%), and 1 bladder graft (0.8%)). The initial serum creatinine level was 16.6 ± 8.8 mg/dL, eGFR was 5.2 ± 3.8 mL/min/1.73m^2, serum urea was 257 ± 123 mg/dL, serum albumin was 3.01 ± 1.3, g/dL, and blood hemoglobin was 8.8 ± 1.4 g/dL. The mean distance from the skin to the peritoneum was 2.5 ± 1.0 cm, and the mean RAM thickness was 0.91 ± 0.3 cm (Table 1).

Catheter implantation achieved technical success in 116 (97.4%) patients. Insertion attempts failed in 3 (2.5%) cases, and

Table 1. Patient demographics and clinical data.

	N = 119 (%)
Age (years)	46.0 ± 17.8
Primary renal disease	
Diabetic nephropathy	28 (23.6)
Hypertension	30 (25.2)
Urologic disease	10 (8.4)
Glomerulonephritis	5 (4.2)
Unknown	46 (38.6)
BMI (kg/m^2)*	23.4 ± 4.5
BMI ≥ 30 kg/m^2	9 (7.5)
Males with central obesity	18 (15)
Females with central obesity	29 (24)
Serum albumin (g/dL)	3.01 ± 1.3
Serum urea (mg/dL)	257 ± 123
Serum creatinine (mg/dL)	16.6 ± 8.8
eGFR (mL/min/1.73m^2	5.2 ± 3.8
Hemoglobin (g/dL)	8.8 ± 1.4
Skin-to-RAM depth (cm)	1.68 ± 0.8
Skin-to-peritoneum depth (cm)	2.59 ± 1
RAM thickness (cm)	0.91 ± 0.3
Catheter dysfunction	30 (25.8)
Migration	21 (63.6)
Omentum adhesions	5 (15.1)
Undetermined Constipation	3 (9.0) 1 (3.0)
Dialysate leakage Insertion failure	2 (1.6) 3 (9.0)

BMI = body mass index; eGFR = estimated glomerular filtration rate; RAM = rectus abdominis muscle.

30 (25.8%) patients presented with catheter dysfunction. Two patients presented with dialysate leakage that resolved with peritoneal rest. Interventions to correct the dysfunction were successful in 3 cases (Table 2). According to univariate analysis, the skin-to-peritoneum distance (3.0 ± 1.2 cm vs. 2.3 ± 0.7 cm, $p = 0.008$) and RAM thickness (1.14 ± 0.1 cm vs. 0.82 ± 0.2 cm, $p < 0.001$) were associated with catheter dysfunction (Table 2). In an attempt to identify the variables associated with PDc dysfunction, a logistic regression analysis was performed. RAM thickness ≥ 1.0 cm, skin-to-peritoneum distance > 2.88 cm, abdominal waist > 92.5 cm, BMI < 18.1 kg/m^2, and skin-to-RAM fascia distance > 2.3 cm were associated with primary PDc dysfunction. According to ROC analysis, RAM thickness ≥ 1.0 cm had a sensitivity of 90% and specificity of 73%, with a positive predictive value (PPV) of 47% and negative predictive value (NPV) of 95% to predict primary PDc dysfunction (OR 1.62, 95% CI 1.42 – 1.85, $p < 0.00$) (Table 3) (Figure 3). The RAM thickness/skin-to-peritoneum ratio was not better associated with PDc dysfunction (AUC of 62%, threshold > 0.45 cm, specificity 0.71, sensitivity 0.53, $p = 0.03$). According to multivariate logistic regression analysis, RAM thickness was the only independent determinant for PDc dysfunction (OR 1.61, 95% CI 1.38 – 1.88, $p < 0.001$) (Table 4).

Discussion

Mechanical factors are a frequent cause of PDc dysfunction and can be traced along the path of dialysate flow. At the abdominal wall level, subcutaneous kinking of the catheter can lead to a slow inflow/outflow dialysis rate [14]. A depth from the skin to the peritoneum ≥ 5.5 cm increases technical difficulty, which can lead to mechanical dysfunction [11]. In this single-center prospective cohort study, we found that RAM thickness was an independent and significant risk factor associated with early PDc dysfunction (OR 1.61 95% CI 1.38 – 1.88, $p < 0.001$) (Table 4). To the best of our knowledge, this is the first study evaluating the association between RAM thickness and PDc outcomes. Similar to Shanmugalingam et al. [11], we found an association between abdominal wall thickness and PDc dysfunction. A skin-to-perito-

Table 2. Diagnostic tests, interventions undertaken, and outcomes in patients with catheter dysfunction.

	(n) (%)	Diagnosis	Intervention/result
Catheter dysfunction	30 (25.8)	Inadequate inflow/outflow	
Constipation	1 (3.3)	Clinical grounds	Enema/successful
Migration	21 (70)	Abdominal X-ray	Flushing/enema/guidewire if failure persisted/successful in 2 cases
Omentum adhesions	5 (16.6)	Tissue recognized at catheter removal	Flushing/unsuccessful
Undetermined	3 (10.0)	All the above negative	Flushing/unsuccessful

Table 3. Univariate logistic regression for variables associated with primary PDc dysfunction.

	PDc dysfunction N = 27 (%)	No PDc dysfunction N = 89 (%)	p
Age (years)	45.6 ± 17	46.0 ± 18	0.37
BMI (kg/m^2)	23.0 ± 5	23.2 ± 4	0.33
Previous abdominal surgery	9 (16.6)	4 (6.1)	0.08
Central obesity	22 (40.7)	23 (35.3)	0.58
Abdominal waist (cm)	95.0 ± 16	91.3 ± 13	0.80
Skin-to-peritoneum depth (cm)	3.0 ± 1.2	2.3 ± 0.7	0.008
RAM thickness (cm)	1.14 ± 0.1	0.82 ± 0.2	0.000
Albumin (mg/dL)	2.8 ± 0.8	2.8 ± 0.7	0.27
Hemoglobin (g/dL)	8.81 ± 1.5	8.75 ± 1.4	0.60

PDc = peritoneal dialysis catheter; BMI = body mass index; RAM = rectus abdominis muscle.

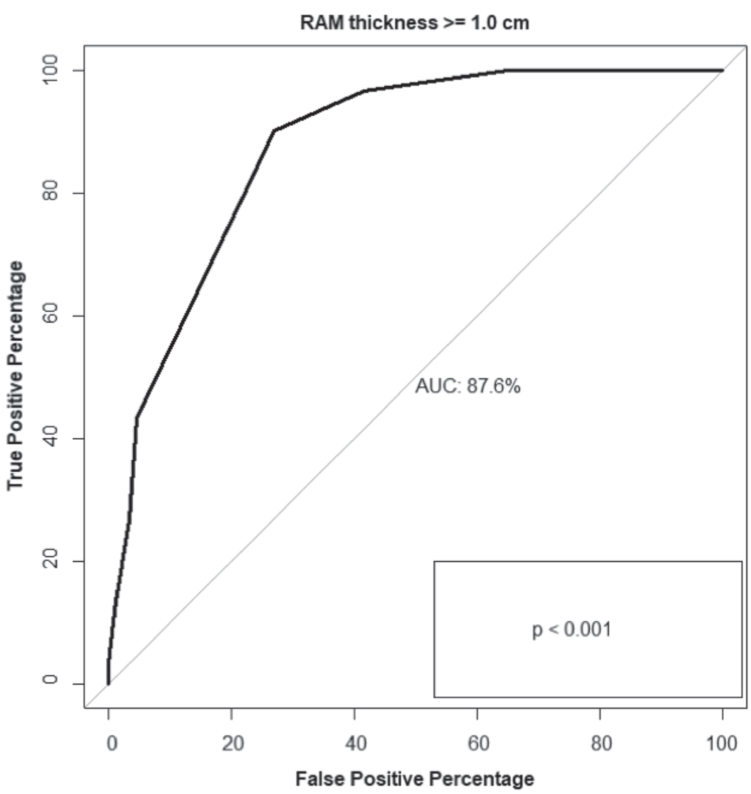

Figure 3. Area under the curve in emergency-start peritoneal dialysis patients predicting peritoneal catheter dysfunction with rectus abdominis muscle thickness ≥ 1.0 cm.

neum depth ≥ 3.0 cm, skin to RAM fascia depth > 2.37, and abdominal waist > 92 cm were associated with PDc dysfunction. However, in the multivariate analysis, only RAM thickness increased the risk of dysfunction. Our patients were significantly younger (46 years) in comparison to patients in other series where the average age was > 60 years [15]. Although we do not have any evidence, we theorize that in younger patients, in addition to an increased skin-to-peritoneum depth, a greater thickness of the RAM might lead to stronger contraction of muscle fibers, thus increasing the risk of catheter dysfunction. A possible explanation for this finding is that the increased thickness of the RAM increases the number of contractile muscle fibers. Considering that the Hanneman's size principle of motoneuron recruitment [16] could apply by extension to the contraction of skeletal muscle [17], the chance of recruiting larger muscle fibers might results in stronger muscle force contraction which will hinder the flow of the dialysate fluid. These findings suggest that ultrasound measurements of RAM thickness can assist in the adequate selection of patients for percutaneous PD catheter insertion and improve the morbidity and mortality associated with early PDc dysfunction.

Our study has several limitations. First, the measurement of the parameters was made after the placement of the PDc, where inflammation of the rectus muscle due to trauma might have increased muscle thickness. Second, although ultrasound metrics were performed by the same nephrologist and the applied pressure to the probe was minimal, it is expected to have measurement errors due to the pressure of the ultrasound probe. Third, the relatively small size of our cohort sample is another limitation. However, given the biological plausibility of our findings, we believe that the results of future studies will yield consistent results. Fourth, the PDc dysfunction rate (22.6%) was higher than the recommended failure rate (≤ 20%) [18]. The higher rate could be explained by the fact that our patients started PD in an urgent and unscheduled fashion immediately after PDc insertion. A higher rate of dysfunction has been reported in other studies when PD is initiated urgently (onset < 24 hours after the insertion) compared to a planned start [15]. Additionally, starting PD in the supine position with a large intraperitoneal volume immediately after catheter placement may increase the risk of catheter displacement due to the floating of the catheter [15]. The strengths of our study are its prospective design and the fact that all ultrasound metrics were performed by one individual, diminishing the risk of inter-rater variability.

Table 4. Summary of the different variables in relation to primary dysfunction after they were dichotomized for best discrimination by the construction of receiver operating characteristic (ROC) curves.

		Sensitivity (%)	Specificity(%)	ROC	p
RAM thickness (cm)	≥ 1.00	90	73	0.87	< 0.001
Central obesity	Positive	40.7	64.6	0.52	0.55
Abdominal waist (cm)	> 92.5	66	53	0.57	0.23
BMI (kg/m^2)	< 18.1	16	96	0.51	0.81
Skin-to-peritoneum depth (cm)	> 2.88	56	71	0.66	< 0.001
Skin-to-RAM fascia depth (cm)	> 2.37	30	89	0.57	0.03
Previous abdominal surgery	Positive	13	89	0.51	0.62
Age (years)	> 63	86	23	0.50	0.90
Serum Hgb (g/dL)	> 7.7	30	80	0.52	0.96
Serum albumin (g/dL)	> 3.1	40	74	0.52	0.75

RAM = rectum abdominis muscle; BMI = body mass index.

Table 5. Univariate and multivariate analyses of variables influencing catheter dysfunction outcomes in the studied patients.

		Univariate (95% CI)	p	Multivariate (95% CI)	p
RAM thickness (cm)	≥ 1.00	1.62 (1.42 – 1.85)	< 0.000	1.61 (1.38 – 1.88)	< 0.000
Abdominal waist (cm)	> 92.5	1.16 (1.00 – 1.36)	0.05*	1.06 (0.90 – 1.24)	0.47
BMI (kg/m^2)	<18.1	1.49 (1.09 – 2.02)	0.01*	1.44 (0.98 – 1.73)	0.06
Skin-to-peritoneum depth (cm)	> 2.88	1.25 (1.06 – 1.46)	0.006*	0.88 (0.73 – 1.07)	0.22
Skin-to-RAM fascia depth (cm)	> 2.37	1.33 (1.08 – 1.65)	0.008*	1.19 (0.95 – 1.50)	0.11
Previous abdominal surgery	Positive	1.06 (0.82 – 1.36)	0.62	0.98 (0.79 – 1.22)	0.91
Age (years)	> 63	0.91 (0.76 – 1.10)	0.36	0.99 (0.83 – 1.18)	0.94
Serum Hgb (g/dL)	>7.7	0.88 (0.73 – 1.07)	0.21	0.99 (0.84 – 1.17)	0.94
Serum albumin (mg/dL)	> 3.1	1.13 (0.95 – 1.34)	0.14	1.09 (0.94 – 1.26)	0.23

RAM = rectum abdominis muscle; BMI = body mass index; Hgb = hemoglobin.

Conclusion

In this single-center prospective cohort of emergency-start PD patients, RAM thickness was associated with primary PDc dysfunction. This finding may assist with the decision of which patients may be suitable for percutaneous PD catheter insertion in urgent situations. Further studies with a larger number of patients must be considered to confirm the generalizability of our findings.

Ethics approval

The research was conducted ethically in accordance with the Declaration of Helsinki. The study was approved by the Institutional Ethical Committee of the Hospital Civil de Guadalajara.

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Conflict of interest

The authors declare that they have no competing interests.

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