Loss of peritoneal function is a major factor leading to failure of treatment in peritoneal dialysis (PD). Although the precise biologic mechanisms responsible for these changes have not been defined, the general assumption is that alterations in peritoneal function are related to structural changes in the peritoneal membrane.

The aim of the present study was to uncover the relationship between functional parameters of peritoneum and peritoneal thickness as measured by ultrasonography.

We studied 43 prevalent patients who had been on PD for at least 12 months in the Ege University PD unit. We recorded body weight, height, age, sex, PD duration, episodes of peritonitis, and results of peritoneal equilibration tests. Parietal peritoneal thickness was measured from four abdominal quadrants at the mid-clavicular line. The peritoneal thickness measurement was determined as the mean of the four separate measurements. (In some cases, the measurement at one of the lower quadrants was excluded from the calculation if the peritoneal catheter was present near the area probed.) Mean peritoneal thickness in the patients was $446 \pm 164 \mu m$ (range: 250 – 930 $\mu m$), which was significantly correlated with mean body weight ($r = 0.31, p < 0.05$), height ($r = 0.31, p < 0.05$), end-to-initial ratio of dialysate glucose ($r = -0.44, p < 0.01$), dialysate-to-plasma creatinine ($r = 0.51, p < 0.01$), and PD duration ($r = 0.48, p < 0.01$).

Peritoneal thickness was positively correlated with time on dialysis, being a median of $370 \mu m$ [interquartile range (IQR): 283 – 400 $\mu m$] in patients who had been on PD for less than 24 months up and 660 $\mu m$ (IQR: 483 – 733 $\mu m$) in patients who had undergone PD for more than 6 years.

What Does Peritoneal Thickness in Peritoneal Dialysis Patients Tell Us?

Ultrasound examination is a simple and noninvasive method of measuring peritoneal thickness in PD patients. It may be useful in the study of peritoneal structure and function. Sequential measurements over time may be useful for early diagnosis of encapsulating peritoneal sclerosis.

**Key words**
Sonography, thickness, peritoneum

**Introduction**
Loss of peritoneal function is a major factor leading to failure of peritoneal dialysis (PD) treatment (1–3). Although the precise biologic mechanisms responsible have not been defined, alterations in peritoneal function are widely assumed to be related to structural changes in the peritoneal membrane. Previously published data suggest that prolonged PD and frequent episodes of peritonitis lead to structural changes and submesothelial thickening (variously described as fibrosis or sclerosis) in the peritoneum (2,4). Those studies did not examine the relationship between functional changes and possible morphologic changes in the peritoneal membrane.

The Peritoneal Biopsy Study Group published its first results in 2002 (5). In that study, they compared the morphologic features of the parietal peritoneal membrane in 130 patients undergoing PD with features of the peritoneal membrane in normal subjects, uremic pre-dialysis patients, and patients undergoing hemodialysis. The median thickness of the submesothelial compact collagenous zone was 50 $\mu m$ for normal subjects, 140 $\mu m$ for uremic patients, 150 $\mu m$ for patients undergoing hemodialysis, and 270 $\mu m$ for patients undergoing PD ($p < 0.001$ for all patients vs. normal subjects).

Thickened of the compact zone increased significantly with duration of PD therapy [0 – 24 months: 180 $\mu m$ ($n = 58$); 25 – 48 months: 240 $\mu m$ ($n = 24$); 49 – 72 months: 300 $\mu m$ ($n = 13$); 73 – 96 months:
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In addition, PD patients with membrane failure exhibited a significantly thicker submesothelial compact collagenous zone (5). In a previous experimental study, we also showed that peritoneal thickness is significantly correlated with functional parameters such as glucose absorption rate and ultrafiltration capacity (6).

Although peritoneal biopsy is the “gold standard” for assessment of peritoneal morphology, it is also a highly invasive test for routine evaluation. The Peritoneal Biopsy Study Group collected 130 biopsy specimens by harvesting them during any surgical procedure that occurred in 130 patients in 20 different centers in Europe and Japan. But is a noninvasive and reproducible test available that can be routinely used to measure peritoneal thickness?

Ultrasonography is a noninvasive modality predominantly used for soft tissues that provides an efficient means of imaging the mesentery and peritoneum. The anterior abdominal wall and the underlying musculature and fat tissue can be effectively evaluated without interference from any structure containing gas or bone. Likewise, high-resolution ultrasonography shows great potential for examining the parietal peritoneum in this bodily area, especially in patients with free fluid in the abdominal cavity. Ultrasonography has been extensively used to evaluate ascites, peritoneal tumors, and other regional pathologies. An excellent population for this type of study is patients on chronic PD. In various earlier studies, ultrasonography has been demonstrated to be effective in evaluating catheter tunnel problems such as infection and the presence of adhesions (7–9).

To our knowledge, only one study on the sonographic evaluation of peritoneal thickness in PD patients has been published (10). The authors of that study suggested the use of ultrasonography in the study of peritoneal changes in pediatric PD patients. No study has investigated the relationship between peritoneal morphology and functional parameters in PD patients.

The aims of the present study were to determine whether ultrasonography of the peritoneum can be performed in a reliable and reproducible fashion, and to uncover the relationship between functional parameters of the peritoneum and peritoneal thickness as measured by ultrasonography.

**Patients and methods**

The study enrolled 43 prevalent patients who had been on PD for at least 12 months in the Ege University PD unit. For these patients, we recorded body weight, height, age, sex, primary kidney disease, PD duration, episodes of peritonitis, and peritoneal equilibration test (PET) results. Measurements of peritoneal thickness were performed by the same radiologist within 3 months before or after the PET.

**Peritoneal thickness measurement**

All measurements were taken using a 13 – 5 MHz linear transducer (high-resolution probe) and a Siemens Antares (Siemens AG, Erlangen, Germany) ultrasound unit. The ultrasonographic measurements were obtained on each of the abdominal quadrants while the patient was lying supine. The probe was held perpendicular to both the mid-clavicular line and the body surface. Measurement of the parietal peritoneum, defined as the inner hyperechogenic line surrounding the abdominal cavity, was obtained on each abdominal quadrant in each patient at the level of the mid-clavicular longitudinal line (see Figure 1). The mean of the four measurements was calculated for each patient. In cases where the peritoneal thickness in one of the lower quadrants could not be obtained because of the presence of the peritoneal catheter, the mean of the remaining three values was calculated.

To assess the validity of measurements, 5 patients were examined on 3 consecutive days. The coefficient of variation was 5%, and the inter-observer error was 6%.

**Statistical analysis**

The Pearson and Spearman correlations were used to analyze correlations between peritoneal thickness and functional parameters. The Kruskal–Wallis test was used to compare groups. A p value of less than 0.05 was considered significant.

**Results**

Of the 43 patients, 22 (51%) were female. Mean age in the group was 49 ± 13 years (range: 23 – 79 years). Primary renal diseases were unknown (n = 21), tubulointerstitial disease (n = 12), chronic glomerulonephritis (n = 4), diabetes (n = 3), and hypertension (n = 3). The mean PD duration was 39 ± 17 months (range: 14 – 84 months).

750 µm (n = 16); >97 months: 700 µm (n = 19)].
Mean peritoneal thickness in the study group was $446 \pm 164 \, \mu m$ (range: 250 – 930 \, \mu m), and this value was significantly correlated with mean body weight ($r = 0.31, p < 0.05$), height ($r = 0.31, p < 0.05$; Figure 2), end-to-initial ratio of dialysate glucose (D/D0; $r = -0.44, p < 0.01$), dialysate-to-plasma (D/P) creatinine ($r = 0.51, p < 0.01$), and PD duration ($r = 0.48, p < 0.01$; Figure 3). Correlation between peritoneal thickness and functional parameters remained significant when peritoneal thickness measurements were adjusted for height (thickness/height) and weight (thickness/weight). No significant correlation was observed with episodes of peritonitis or number of exit-site infections.

Peritoneal thickness showed a positive correlation with time on dialysis. It progressed from a median of $370 \, \mu m$ [interquartile range (IQR): 283 – 400 \, \mu m] in patients who had been on PD for less than 24 months to $660 \, \mu m$ (IQR: 483 – 733 \, \mu m) in patients who had been on PD for more than 6 years (Figure 4, Table I). No differences were observed in mean thickness between groups of patients with or without a history of peritonitis.

**Discussion**

Various studies have demonstrated that ultrasonography is an effective means of evaluating catheter tunnel problems such as infection and adhesions in the PD population (7–9). Our results suggest that ultrasonography may also provide early detection of morphologic changes.

To our knowledge, only one other study on the sonographic evaluation of peritoneal thickness in PD patients has been published. Although Faller et al. recorded that peritoneal ultrasonography findings differ between healthy subjects and patients on PD, those authors did not investigate the relationship between peritoneal morphology and functional parameters in their study. They clearly showed that peritoneal thickness increases with age and body size, and based on
However, the study by Faller et al. may contain technical biases, because in our study, all measurements of peritoneal thickness were smaller than theirs. We speculate that their measurements included both fasciae of the abdominal musculature and the fat layer below the connective tissue and peritoneum. This result can occur with the use of a low-resolution ultrasonography probe (5 MHz). In our study, we used high-resolution ultrasonography probes (13 MHz), which minimize technical error.

Williams et al. showed that the median thickness of the submesothelial compact zone of the parietal peritoneal membrane in normal biopsies is 50 µm. Those findings differed from the results of an earlier small study in which “simple sclerosis” was said to be present if the submesothelial layer was thicker than 20 µm (11). More recently, a comprehensive review of studies in this field (12) emphasized that the thickness of the submesothelial tissue in simple sclerosis does not exceed 40 µm. Indeed, the authors pointed out that PD should be suspended if the submesothelial layer reaches more than 40 µm in thickness. On the other hand, in another study, the thickness of the normal peritoneal membrane was recorded as 327 µm (13).

The possibility of coexistent intraperitoneal inflammation, which can influence the peritoneal thickness measured in patients undergoing elective surgery, is impossible to rule out. The wide variation in observed membrane thicknesses also highlights possible variability in sampling and the need to obtain biopsies in a standardized way.

The biopsy samples obtained from patients undergoing PD demonstrated progressively increasing thickness with a significant correlation with duration their findings, they suggested the use of ultrasonography to evaluate peritoneal changes in pediatric PD patients (10).

In agreement with those findings, we also observed that peritoneal thickness increases with body weight and height. Contrary to those findings, we did not observe a difference in peritoneal thickness between patients with and without a history of peritonitis.
of PD (5), as we similarly observed in our study. Our ultrasonographic results were approximately 40% higher than the histologic results (Table I). This discrepancy may be the result of fixation of the tissue samples with formalin and alcohol.

Ours is the first study to compare peritoneal thickness by ultrasonography with peritoneal function. We found that ultrasonographic measurement of peritoneal thickness correlated significantly with functional parameters such as D/P creatinine and D/D₀ glucose. Increased peritoneal thickness correlated inversely with the glucose absorption rate and increased D/P creatinine, both of which lead to membrane failure. In agreement with our findings, a subgroup analysis of the biopsies from patients on PD demonstrated that the thickness of the submesothelial compact zone in patients who underwent biopsies during transplantation or incidental surgery was significantly less than that seen in patients who underwent catheter-related surgery or who experienced membrane failure (5).

Conclusions
Sonography is a precise, simple, reproducible, and noninvasive method of measuring peritoneal thickness in PD patients. Sonography may be useful in showing sequential changes in peritoneal structure and function. In the long term, sonography may be useful for early diagnosis of encapsulating peritoneal sclerosis.

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Corresponding author:
Soner Duman, Ege Üniversitesi Tip Fakültesi, İç Hastalıkları Ana Bilim Dali, Nefroloji Bilim Dali, Bornova 35100, İzmir, Turkey.
E-mail: soner.duman@ege.edu.tr, sonerduman@hotmail.com