CASE REPORT

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The use of remote patient management in early diagnosis of ultrafiltration failure in peritoneal dialysis

ABSTRACT

The SARS-CoV-2 pandemic has turned the whole world towards telemedicine. Remote patient management is a relatively new trend in managing peritoneal dialysis patients. It has gained importance in the current epidemiological situation. This article presents new possibilities and hopes related to promoting this type of patient supervision. Special attention was paid to the dynamics of ultrafiltration changes in various pathological conditions.

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Key words: remote patient management, peritoneal dialysis, ultrafiltration failure

INTRODUCTION

Peritoneal dialysis (PD) as renal replacement therapy at home is associated with patients' much greater independence and autonomy compared to hemodialysis (HD), and, therefore, it has seen a growing interest among patients, especially recently. The foundation of effective PD is thorough adherence to medical recommendations, as well as early detection and reporting of emerging problems. Therefore, the role of good cooperation and efficient communication between the patient and the Peritoneal Dialysis Group to minimize complications and optimize the effects of therapy cannot be overestimated. Those needs are met by telemedicine and remote patient management systems (RPM).

The program for remote patient management of peritoneal dialysis patients available in Poland is based on the Homechoice Claria™ cycler connected to a modem, which transmits data via a mobile phone to the Sharesource™ platform, where they can be read via the Internet connection in the PD Outpatient Unit. The clinical team can review daily Automated Peritoneal Dialysis (APD) therapy records, including pertinent alerts regarding specific results of adherence to treatment recommendations, lost time of dialysis, lost dwell time, lost prescribed fluid volume, early termination of drainage, total ultrafiltration, blood pressure, and patient's weight. By using modern communication tools, this new way of delivering care in PD can improve the availability of medical staff and the quality of time spent on patient care [1].

Mainly by increasing the patient's compliance and self-awareness, RPM programs lead to better clinical outcomes. The literature confirms that the use of remote monitoring is associated with longer technique survival, improved blood pressure control, as well as reduced hospitalization frequency, length of hospital stay, and health care costs [2]. Medical staff, having constant access to records of each patient's dialysis sessions, more often decide to introduce corrections to the given patterns, making the therapy truly individual and tailored to the patient's needs [3].

The possibility of remote patient surveillance has gained importance during the SARS-CoV-2 pandemic. Patients with chronic kidney disease (CKD) who require dialysis were at high risk of severe COVID-19 [4]. Faced with this challenge, home therapy with peritoneal dialysis, in particular with Automated Peritoneal Dialysis with Remote Therapy

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Management (APD-RPM) programs, has been used to reduce risk and prevent infection. On March 28, 2020, the International Society for Peritoneal Dialysis (ISPD) published guidelines on management during the pandemic, in which they strongly recommended remote monitoring of patients as the main method of management for peritoneal dialysis [5]. As shown in numerous retrospective studies, patients willingly took advantage to possibly avoid transportation and showing for visits in person, which was associated with reduced exposure to SARS-CoV-2. At the same time, patients were aware that the medical team watches over their treatment and has insight into current events, and, therefore, patients felt safe. There was no significant negative effect of this model of care, patients were properly cared for, and the proactive actions of the clinical team allowed for early identification of emerging problems [1, 6–8].

Peritoneal dialysis as a form of renal replacement therapy improves survival in the early period after initiation of therapy, and it preserves residual renal function for longer but is associated with a 10-times greater risk of technique failure compared to hemodialysis. The Australia and New Zealand Dialysis and Transplant Registry reported infections in 52%, inadequate dialysis in 18%, mechanical problems in 19%, and social problems in 11% of patients as the reasons for conversion from PD to HD. The use of RPM in everyday practice gives the Peritoneal Dialysis Teams new diagnostic possibilities. Regular monitoring of records of performed procedures in relation to the patient's clinical condition enables staff to acquire more and more experience and helps in the early detection of ultrafiltration failure, drainage problems, and identification of failures caused by patient noncompliance [9].

RPM IN DIAGNOSIS OF ULTRAFILTRATION FAILURE

Maintaining adequate hydration is one of the main tasks of renal replacement therapy. Overhydration carries a number of unfavorable clinical sequelae, including congestive heart failure. Ultrafiltration failure should be treated as an important problem among patients receiving peritoneal dialysis, and it should lead to a search for the underlying causes.

Among the reasons for decreased ultrafiltration (UF), we can distinguish:

— lack of cooperation of the patient,
— inadequate parameters of treatment: too long dwell time, too low glucose concentration in the dialysis fluid,
— intensification of opposing mechanisms: direct lymphatic absorption and absorption of fluids into tissues,
— peritoneal dysfunction:
  • high transmembrane transport: inborn disorders, recent peritonitis, long-term PD,
  • loss of the functional surface of the peritoneal membrane: adhesions, fibrosis,
— mechanical failures: catheter dysfunction (narrowing of the lumen, displacement), retroperitoneal leakage, hernia [10].

The RPM enables observation and analysis of both short-term ultrafiltration failures that healthcare professionals notice when browsing the database on a daily basis and searching for patterns of change in long-term follow-up. Therefore, it becomes a helpful tool not only in everyday practice but also a source of medical data so that changes occurring over several years of treatment may be recreated.

In the following sections of this article, we present cases when RPM helped spot changes in ultrafiltration in various clinical situations.

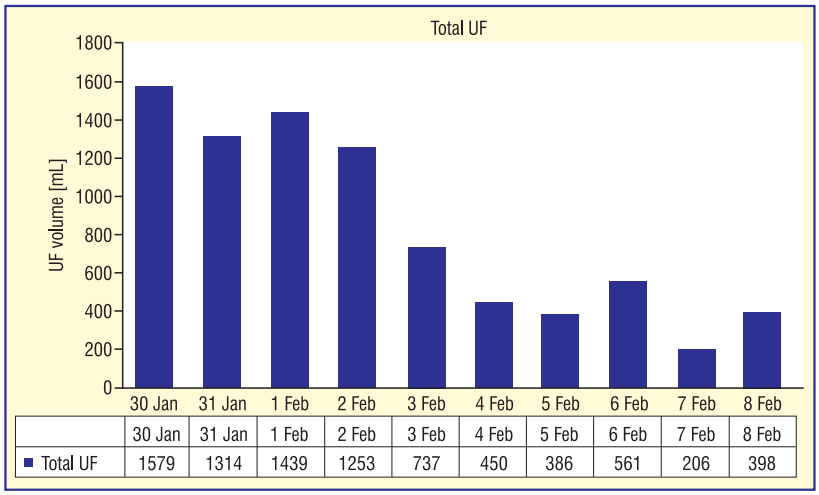
CASE 1: PERITONEAL DIALYSIS (PD) PERITONITIS

A 56-year-old man was diagnosed with end-stage renal disease of unknown etiology. He had been treated with peritoneal dialysis since December 2017. The APD-RPM system in the PD-plus regimen (APD with additional evening fluid exchange). On February 9, 2020, he was admitted to the Department due to malaise, abdominal pain, flatulence, feeling of abdominal fullness, and a reduced volume of dialysate flowing out, which was also cloudy and accompanied by symptoms of fluid overload. Based on the clinical presentation and abnormal peritoneal fluid cytosis, peritoneal dialysis peritonitis was diagnosed and empirical antibiotic therapy was initiated, and after the cultures were obtained, the treatment was modified based on the antibiogram results.

When analyzing the course of treatment on the Sharesource™ platform, it was noticed that the decrease in ultrafiltration occurred even before the onset of symptoms. UF, which was previously 1400 mL daily, was getting lower over the next few days (Fig. 1). The vasoactive action of inflammatory mediators influences peritoneal transport by recruiting more peritoneal capillaries, which increases the effective surface area of the membrane. As a re-

sult, the permeability of the filter membrane is increased [11]. This has been confirmed by studies carried out in the 1980s. It was shown that during episodes of peritonitis, peritoneal permeability increases significantly and returns to baseline values after the infection resolves [12].

The potential of the RPM was noticed by Rojas-Diaz M. and Ramos A., who presented the results of a retrospective analysis of 10 patients at the Congress of the American Society of Nephrology in 2017; there was a statistically significant decrease in the ultrafiltration volume one day before symptoms of peritonitis developed [13].



	30 Jan	31 Jan	1 Feb	2 Feb	3 Feb	4 Feb	5 Feb	6 Feb	7 Feb	8 Feb
Total UF	1579	1314	1439	1253	737	450	386	561	206	398

Figure 1. Ultrafiltration drop in a patient with dialysis peritonitis. UF — ultrafiltration

GENERALIZED INFLAMMATION

CASE 2

A 31-year-old female was diagnosed with CKD due to lupus nephropathy. She started renal replacement therapy with HD with a permanent catheter as vascular access. In 2017, she sustained numerous bacterial infections: a few episodes of sepsis and subcutaneous abscesses. Due to the multitude of blood-borne infections, in February 2018 it was decided to convert to APD with possible RPM. With urine output of about 1000 mL daily, adequate dialysis with UF was obtained at the level of 500–600 mL per session.

At the end of May, there was a significant decrease in UF to an average of 180 mL daily (Fig. 2). The patient was invited for a follow-up visit. The woman came in good general condition, she was being treated with an antibiotic for otitis media. Laboratory tests revealed hypokalemia and anemia with hemoglobin concentration of 8 g/dL. The patient was offered hospitalization to which she did not consent. During the next few days, there was a rapid deterioration in her general condition with an increase in the inflammatory parameters. The patient was admitted to the hospital. Deep phlegmon of the left thigh was diagnosed in the area of the hip joint replacement (the patient underwent total hip replacement in 2013–2014; the prosthesis was probably colonized secondary to infectious complications in 2017). PD sessions were continued during her hospital stay. Over the first 2 weeks of treatment (with empirical antibiotic therapy, followed by targeted antibiotics), UF fluctuated at around 120 mL, then a gradual return of the ultrafiltration volume to the level of 400–500 mL per session was observed.

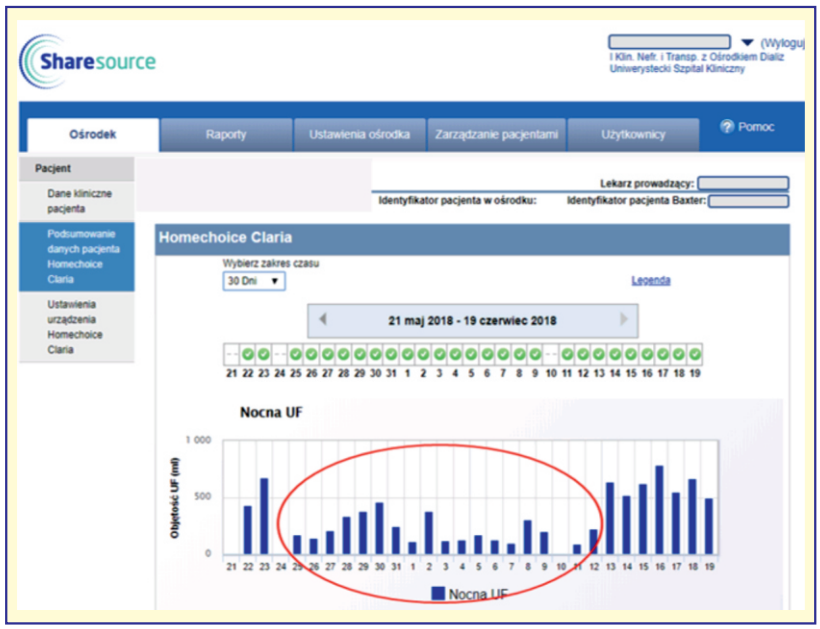


Figure 2. Ultrafiltration drop in a patient with generalized inflammation. Lowered UF preceded development of clinical symptoms. UF — ultrafiltration

CASE 3

A 48-year-old man was diagnosed with end-stage renal disease due to type 1 diabetes and had been treated with peritoneal dialysis since 2019. On March 5, 2021, he was admitted to the surgical ward due to diabetic foot syndrome of the left foot with critical ischemia and necrosis of the second toe and the metatarsus. Necrosis had been progressing for about a month. Laboratory tests showed increased markers of inflammation: leukocytosis 24.4 k/μL, CRP 154.3 mg/L. The patient was qualified for amputation of the left lower limb below the knee level. The operation was

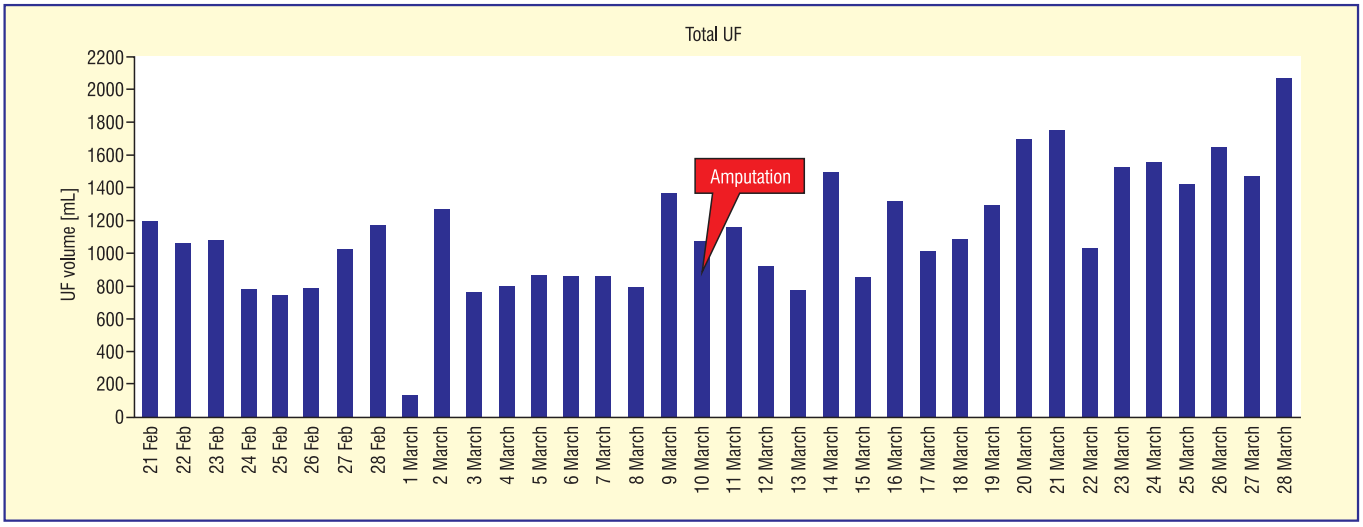


Figure 3. Ultrafiltration failure in a patient with foot necrosis. Gradual improvement was observed following amputation and initial wound healing. UF — ultrafiltration

performed on March 10. The wound was healing properly and five days later the patient was discharged home.

The described patient was included in the RPM program. As a result, the staff of the Peritoneal Dialysis Outpatient Clinic could check the impact of those events on dialysis on an ongoing basis. During progression of inflammation and necrosis, periodical slight to moderate decreases in the UF volume were observed. UF dropped significantly about a week before surgery. After removing the source of inflammation, which was the necrotic tissues of the foot, and healing the wound, UF gradually increased to the values reached before the development of the diabetic foot (Fig. 3).

The presented cases indicate possible loss of ultrafiltration volume as a reaction to generalized acute inflammation developing outside the peritoneum [1]. It can be hypothesized that not only peritonitis but also other infections have a similar effect on the increase in peritoneal permeability. Observing a sudden decrease in the ultrafiltration volume with the use of RPM should in all cases trigger actions aimed at explaining the cause of this drop, such as a call for a control visit.

CASE 4: EXTRAPERITONEAL LEAK

In July 2021, a 61-year-old patient with a history of renal failure due to IgA nephropathy, who had been undergoing peritoneal dialysis since May 2019, presented to the Department for conversion from CAPD to APD. The patient agreed to join the RPM program and received a cycler with a modem transmitting data to the cloud.

This seemingly simple and quick hospitalization was prolonged — initially due to an abscess of the abdominal subcutaneous tissue, and then due to a suspected pleural leak. Before the diagnosis was established, the patient left the hospital on request. A week later, the man visited the Peritoneal Dialysis Outpatient Clinic due to a sudden onset of penile and scrotal swelling — a dialysis fluid leak was suspected. The patient was converted to hemodialysis.

Based on the data from Sharesource™, it was possible to observe a sudden drop in ultrafiltration just before the onset of clinical symptoms. The UF values so far oscillated at a level above 1200 mL daily. The ultrafiltration achieved just before the appearance of the edema was only 619 mL — this indicated the moment of fluid reaching the retroperitoneal space (Fig. 4).

Sudden, significant drops in ultrafiltration are usually caused by mechanical causes — catheter dysfunction or retroperitoneal leak. A group of scientists from Hong Kong in their 5-year observational study on a group of 743 patients, having excluded catheter dysfunction, identified 36 cases of a sudden decrease in ultrafiltration (≥ 50%), 23 of which were associated with retroperitoneal leak confirmed on imaging [14]. Risk factors for mechanical injury to the peritoneal membrane include use of large volumes of dialysis fluid, frequent sitting or standing, isometric exercises, Valsalva maneuver (e.g. when coughing, pressing), recent abdominal surgery, and obesity. The exclusion of leaks as the cause of a sudden drop in UF is particularly important in patients with a history of hernia or commu-

nication between the peritoneal cavity and the pleural cavity [15].

CASE 5: HYPERGLYCEMIA

A 30-year-old patient with CKD and type 1 diabetes started APD-RPM therapy in July 2020. On February 20, 2021, the patient experienced nausea, vomiting, and abdominal pain. Those symptoms started suddenly. On the next day, the patient presented to the ED and was then admitted to the 1st Department of Nephrology. On admission, the cytosis of the peritoneal fluid was determined, excluding dialysis peritonitis. The markers of inflammation were normal, but severe hyperglycemia was noticed (about 500 mg/dL). The treatment consisted of a continuous infusion of short-acting insulin, followed by intensive insulin therapy, which resulted in normalization of glycemia and resolution of symptoms.

Based on the course of dialysis cycles recorded on individual days in the Sharesource™ system, it is possible to determine the impact of those events on the achieved ultrafiltration (Fig. 5). The established treatment program consisted of four overnight fluid exchanges with 1.36% dialysis fluid and a long daily exchange with icodextrin fluid.

One of the factors influencing the amount of ultrafiltration is the concentration gradient of the osmotically active agent [11]. In this presented case, the agent was glucose in the night cycles. High serum glucose levels reduced the difference in levels between blood and dialysis fluid, resulting in reduced or even negative ultrafiltration values. The results of daily

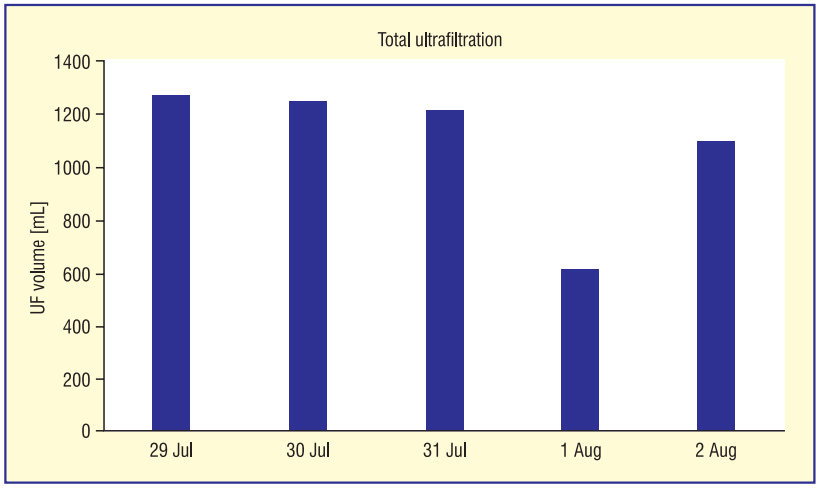


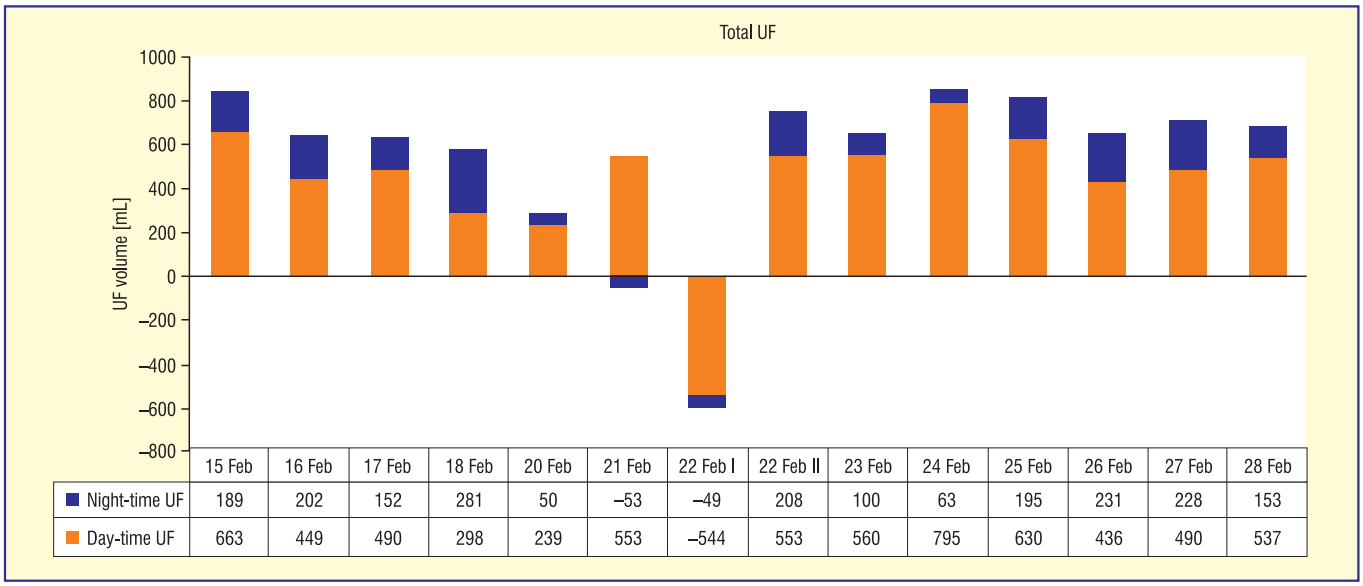
Figure 4. Ultrafiltration drop reflecting extraperitoneal leak. UF — ultrafiltration

retention were more stable, which, due to the use of icodextrin, was not associated with the gradient loss. We attribute the negative result of daily ultrafiltration on February 22 to severe dehydration caused by vomiting.

In patients with diabetes mellitus, the control of hyperglycemia may enable better ultrafiltration without a need for highly hypertonic glucose solutions. Since glycemic control is nowadays largely monitored and modified by patients themselves, patient education about its importance for the adequacy of dialysis is extremely important [10].

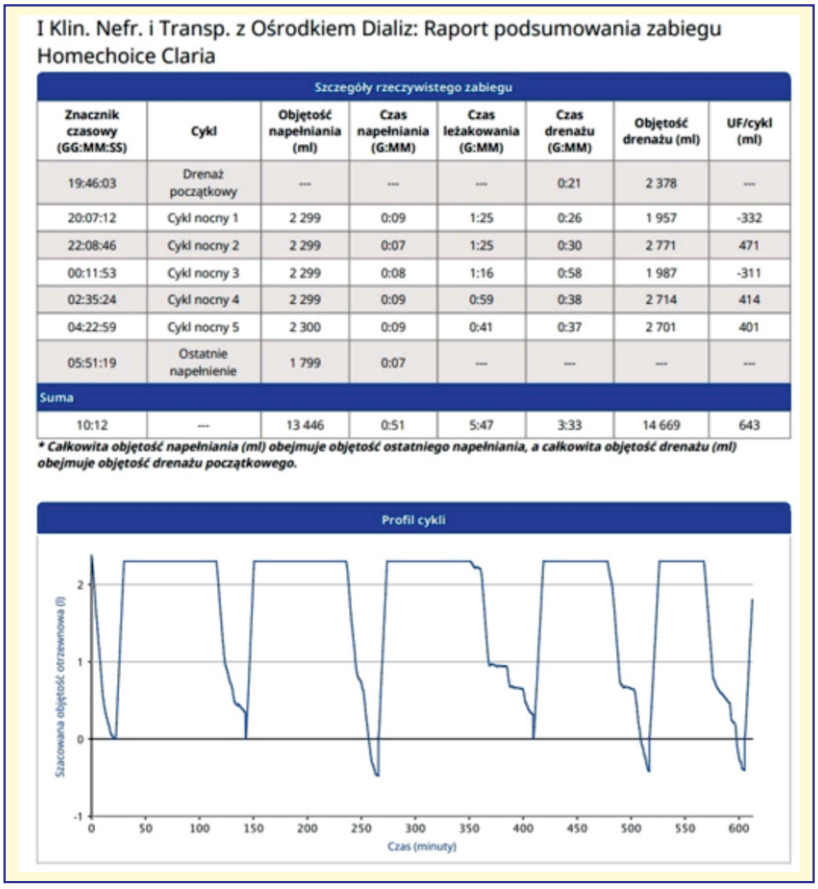
CASE 6: TRANSLOCATION OF THE PERITONEAL DIALYSIS CATHETER TIP

A 49-year-old man had been treated with peritoneal dialysis since 2019 for renal failure



	15 Feb	16 Feb	17 Feb	18 Feb	20 Feb	21 Feb	22 Feb I	22 Feb II	23 Feb	24 Feb	25 Feb	26 Feb	27 Feb	28 Feb
Night-time UF	189	202	152	281	50	–53	–49	208	100	63	195	231	228	153
Day-time UF	663	449	490	298	239	553	–544	553	560	795	630	436	490	537

Figure 5. Ultrafiltration drop during hyperglycemic episode in a patient with type 1 diabetes. UF — ultrafiltration



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Szczegóły rzeczywistego zabiegu

Znacznik czasowy (GG:MM:SS)	Cykl	Objętość napełniania (ml)	Czas napełniania (G:MM)	Czas leżakowania (G:MM)	Czas drenażu (G:MM)	Objętość drenażu (ml)	UF/cykl (ml)
19:46:03	Drenaż początkowy	---	---	---	0:21	2 378	---
20:07:12	Cykl nocny 1	2 299	0:09	1:25	0:26	1 957	-332
22:08:46	Cykl nocny 2	2 299	0:07	1:25	0:30	2 771	471
00:11:53	Cykl nocny 3	2 299	0:08	1:16	0:58	1 987	-311
02:35:24	Cykl nocny 4	2 299	0:09	0:59	0:38	2 714	414
04:22:59	Cykl nocny 5	2 300	0:09	0:41	0:37	2 701	401
05:51:19	Ostatnie napełnienie	1 799	0:07	---	---	---	---
Suma							
10:12	---	13 446	0:51	5:47	3:33	14 669	643

** Całkowita objętość napełniania (ml) obejmuje objętość ostatniego napełniania, a całkowita objętość drenażu (ml) obejmuje objętość drenażu początkowego.*

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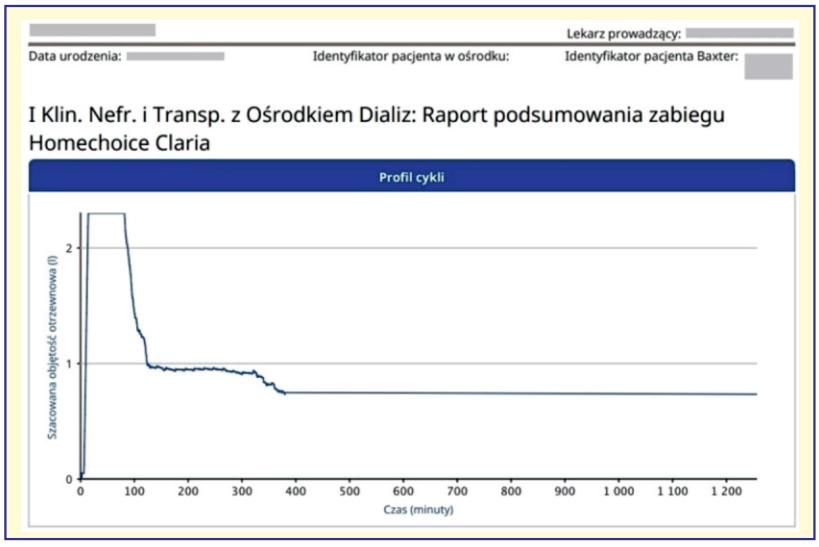
Figure 6. Drainage failure. There is a visible prolongation of drainage time, particularly during the third cycle. UF — ultrafiltration



Lekarz prowadzący:

Data urodzenia: Identyfikator pacjenta w ośrodku: Identyfikator pacjenta Baxter:

I Klin. Nefr. i Transp. z Ośrodkiem Dializ: Raport podsumowania zabiegu Homechoice Claria

Profil cykli

Figure 7. Drainage failure; Automated Peritoneal Dialysis cycles were discontinued

due to type 1 diabetes. The patient was a user of the Homechoice Claria™ cycler and was monitored with the RPM program. In the records of his dialysis sessions, there were flags added periodically, indicating loss of dwell

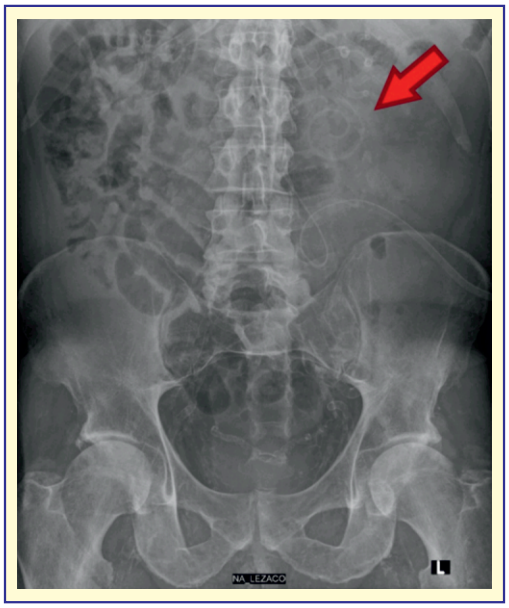


Figure 8. Pig-tail peritoneal dialysis catheter visible at the level of L2–L3 on the left without any significant bends

time associated with an extension of individual drainages (Fig. 6). In June 2021, the flags appeared more and more often. Since July 12, there had been a sudden drop in ultrafiltration. On that day, due to persisting diarrhea mixed with blood, the patient was admitted to the Department of Gastroenterology. During his hospital stay, he experienced anterolateral STEMI (ST Elevation Myocardial Infarction) myocardial infarction. The patient was transferred to the Cardiology Department with an Intensive Cardiac Care Unit, where PCI was performed and two stents were implanted. On the next day, Clostridioides difficile enteritis was diagnosed. Oral vancomycin was initiated.

Because of remote patient monitoring, the team of the Peritoneal Dialysis Outpatient Clinic noticed the complete ineffectiveness of dialysis (Fig. 7). The ineffectiveness of dialysis was confirmed in the Department of Nephrology — a very slow inflow and drainage of the dialysis fluid was observed despite infusion of heparin into the bag. Dialysis peritonitis was excluded. An abdominal X-ray was obtained — the catheter tip was visible in the middle epigastric region (Fig. 8). An unsuccessful attempt was made to non-invasively correct the position of the catheter by administering lactulose and performing enemas. The patient accepted the decision to convert to hemodialysis. Due to a recent myocardial infarction and dual antiplatelet therapy, the repositioning or removal of the PD catheter was postponed.

To identify the cause of catheter dysfunction, it is useful to record dialysis fluid inflow and drainage. If there is a problem with filling, the presence of fibrin or clots in the lumen of the catheter should be suspected. Another clue in such a situation is the presence of fibrin in the dialysis bag (the so-called jellyfish). Intestinal wrapping of the catheter should be suspected in patients with chronic constipation. An abdominal X-ray may show migration of the catheter tip, but not the underlying cause. Remained inflow with no drainage suggests omental wrapping of the catheter. Nevertheless, in most cases, the exact cause of drainage failure is diagnosed only based on direct visualization [16].

The Sharesource™ platform makes it possible to easily identify exactly when the inflow or drainage problem occurred by viewing cycle profiles presented on the graph of estimated peritoneal volume versus time. A detailed record of the actual course of dialysis sessions shows the filling and drainage times and the impact of any delays on lost treatment time.

RPM AS A RELIABLE INDICATOR OF THE QUALITY OF PATIENT COOPERATION

We consider it a sign of non-compliance with the peritoneal dialysis regime when less than 90% of the prescribed fluid exchanges are performed. The overall skipping rate for continuous ambulatory peritoneal dialysis was estimated to be 2.6–53%, and 5–20% for automated peritoneal dialysis [2]. A lack of patient cooperation is directly related to increased mortality, inevitable conversion to hemodialysis, and more frequent and longer hospitalizations [2]. Identification of non-compliance based on RPM can save us from tedious and costly diagnostic workup and direct our efforts towards better education and motivation of patients.

SUMMARY

The use of telemedicine in peritoneal dialysis therapy can be described as one of the most significant events in the history of dialysis. The introduction of memory cards followed by RPM offered the benefits of longer survival of the technique and reduction of complications and treatment costs. APD is the method of choice for younger patients who want to keep an active lifestyle despite their condition. The continuous development of the cycler's technical capabilities is a tribute to both the patient and the medical staff. Modern cyclers enabling two-way communication between the patient and the dialysis center significantly increase the level of patient safety and satisfaction [17].

The Sharesource™ platform provides better active patient care. It enables early identification of factors important for survival of the technique, such as catheter dysfunction or patient cooperation.

Catheter dysfunction is one of the most common causes of early method failure and conversion to HD, so early detection and initial diagnosis based on the records available on the platform can be very helpful for clinicians.

Peritonitis, the most common complication of PD, has a negative impact on technique survival. As it changes the nature of the peritoneal membrane, it is a risk factor for a life-threatening complication called sclerosing encapsulating peritonitis (SEP). So, the prospect of using the trend of ultrafiltration changes to identify acute conditions is promising although the practical application of this observation (e.g. by appropriate setting of alarm parameters) may be difficult, partly due to the inter- and intra-individual variability of the diurnal UF [18].

Finally, it is worth mentioning that implementation of a remote monitoring system for patients improves their quality of life and increases satisfaction with the treatment method, which is undoubtedly an advantage and encourages further improvements of this type of solutions. [19]

Thanks to RPM systems, it is possible to make an initial diagnosis of ultrafiltration failure based on the dynamics of its changes occurring on consecutive days and the identification of mechanical disorders. Further observations and studies utilizing this tool will certainly contribute to extending possibilities of remote diagnosis in peritoneal dialysis patients.

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