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CASE REPORT

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Clinic- and home-based renal rehabilitation improves spKt/V and uremic syndrome in hemodialysis patients: a case report

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Abstract
There was an increasing uptake of hemodialysis and patient life expectancy due to improved treatment efficiency. However, the quality of life (QOL) of chronic kidney disease (CKD) patients is not parallelly improved, leading to a shift in focus towards promoting the QOL. Among the common complications of CKD such as anaemia and mineral bone disorder, uremic syndrome has been found as the main contributor to poor QOL. We present the case of an 80-year-old man with hemodialysis, who presented with poor appetite and weakness following recovering from COVID-19. Biochemical, echocardiographic, body composition, psychological, nutritional, and QOL assessments suggested multi-organ dysfunction attributable to uremic syndrome. Renal rehabilitation involving the combination of clinic- and home-based exercise and nutritional interventions effectively improved his symptoms while elevating spKt/V. Our case report not only demonstrated exercise and nutritional rehabilitation as an effective approach to managing uremic syndrome in hemodialysis patients, but also provided insight into the effects of improved nutritional status on spKt/V.

Keywords Hemodialysis, Renal rehabilitation, spKt/V, Uremic syndrome

Introduction

Kidney failure is considered one of the leading cause of morbidity and mortality worldwide. Hemodialysis (HD) is the most common modality of renal replacement therapy for end-stage kidney disease (ESKD) patients, and its rate of uptake has been increasing in China [1]. However, the health-related quality of life (QOL) of HD patients is often poor, resulting in the risk of hospitalization and death [2]. Observational studies have further found poorer QOL among chronic dialysis patients compared to those with kidney transplant, implying that adequacy in renal clearance may be important in influencing clinical outcomes and QOL [3, 4]. In line with this, increasing focus has been placed on the development of more intensive hemodialysis regimes [5, 6]. Uremic syndrome refers to the accumulation of uremic solutes in the plasma, which can lead to metabolic and signalling derangement, resulting in multi-organ dysfunction and poor patient prognosis [7]. Sarcopenia, uremic cardiopathy (type IV cardiorenal syndrome), and neurological complications are among the prominent manifestations of uremic syndrome [8–10]. Renal rehabilitation is defined as a long-term comprehensive program aimed to improve

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the physical and psychological effects of chronic kidney disease, as well as prolong life expectancy. Among the range of interventions involved, exercise and nutritional therapies have been considered the fundamental aspects of rehabilitation [11]. In this report, we present a case of effective alleviation of uremic syndrome with renal rehabilitation involving combined clinic- and home-based exercise and nutritional interventions.

Case report

An 80-year-old man with ESKD had been managed with hemodialysis three times a week for 92 months without any significant complaint in hemodialysis center. His primary disease, ANCA-related vasculitis, remained stable with mycophenolate mofetil and low-dose prednisone. He had a history of hypertension and coronary vascular disease, and was prescribed a beta-blocker, angiotensin receptor blocker, and anti-platelet medication. He maintained light-intensity physical activity. His symptoms started in January 2023 following an episode of COVID-19 infection. Laboratory test results including hemoglobin, albumin, liver function, and serum lipid were unremarkable at that time. Meanwhile, his dialysis adequacy remained normal with spKt/V at 1.55–1.60, alongside normal blood pressure of 105–122/54–64 mmHg. All the dialysis parameters were listed in the supplementary materials. These symptoms persisted until May 2023 with no improvement. As the renal rehabilitation clinic started operation, he came to the clinic for advice. Besides biochemical tests, echocardiogram was also evaluated, showing that he had HFpEF, ie, heart failure with preserved systolic function. Body composition was evaluated using a multi-frequency bioelectrical impedance analysis device (InBody S10, Biospace, Seoul, Korea; BCM, Fresenius Medical Care, Germany). Physical function was assessed in terms of grip strength and 6-minute walking distance, both of which were noted to be reduced according to the criteria of the Asian Working Group for Sarcopenia criteria [12]. Psychological evaluation using the 9-item Patient Health Questionnaire (PHQ-9) and 7-item Generalized Anxiety Disorder scale (GAD-7) suggested moderate-to-severe depression (PHQ-9 score 11). QOL was assessed using the 12-item Short Form Health Survey (SF-12). Daily energy intake (DEI) and daily protein intake (DPI) were 27.3 $kJ \cdot kg^{-1} \cdot d^{-1}$ and 0.77 $g \cdot kg^{-1} \cdot d^{-1}$, respectively. All baseline data are shown in Table 1 and Supplemental Table 1.

Based on the independence of the patient, a combined clinic- and home-based renal rehabilitation approach was opted for. The program consisted of 4 main components [11]: (1) resistance training of the upper limb, lower limb, and core muscle group; (2) balance training, including single- or double-leg balancing; (3) aerobic training, recumbent power bicycle with tolerable resistance

Table 1 Cardiac function, body composition, psychological status, physical function, nutritional status and quality of life of the patient

	Cardiac function					Body composition						Psychological status		Physical function		Nutritional status		Quality of life
	LVIDs (mm)	LVIDd (mm)	EF (%)	E/E'	CO (ml/min)	BMI (kg/m2)	Body fat (kg)	Body fat percentage (%)	Skeletal muscle (kg)	SMI (kg/m2)	Dry weight (kg)	GAD-7	PHQ-9	GS (kg)	6-min walking distance (m)	DEI (kJ·kg-1·d-1)	DPI (g·kg-1·d-1)	SF-12
Baseline	41	26	65	12	3	17.9	13.9	26.8	21	7.3	51.8	3	11	22.3	342	27.3	0.77	36
3-month post-rehabilitation	42	27	65	8.8	4.2	18.9	14.6	26.7	22	7.6	54.6	1	7	24	408	40.57	1.07	35
Change (% baseline)	2.44	3.85	0.00	−26.67	40.00	5.59	5.04	−0.37	4.76	4.11	5.41	−66.67	−36.36	7.62	19.30	48.61	38.96	−2.78

Abbreviations: LVIDs, end-systolic left ventricular internal diameter; LVIDd, end-diastolic left ventricular internal diameter; CO, cardiac output; BMI, body mass index; SMI, skeletal muscle mass index; GAD-7, 7-item Generalized Anxiety Disorder scale; PHQ-9, 9-item Patient Health Questionnaire; GS, grip strength; DEI, daily energy intake; DPI, daily protein intake; and SF-12, 12-item short form health survey

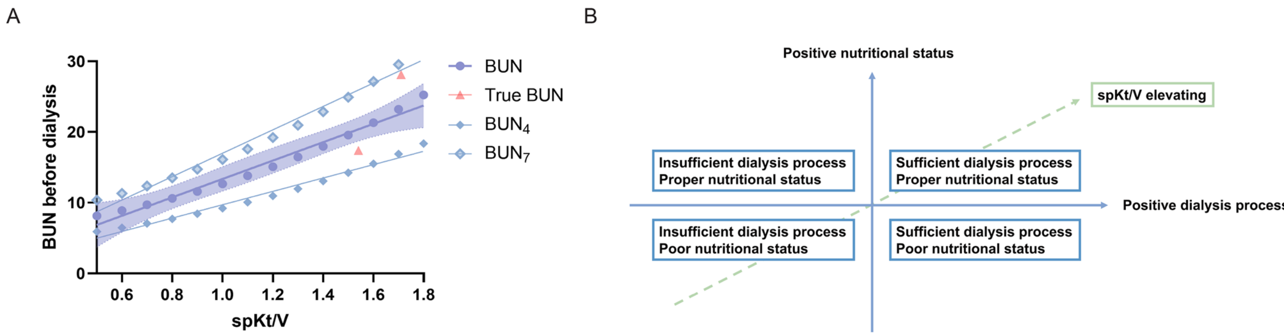

Fig. 1 (**a**) Correlation plots for spKt/V and serum BUN. Labels: BUN, post-dialysis BUN of 5.5 mmol/L ± 95% CI; True BUN, the two example results of our patient; BUN_4, post-dialysis BUN set at 4 mmol/L; and BUN_7, post-dialysis BUN set at 7 mmol/L. (**b**) spKt/V directly influenced by dialysis adequacy and nutritional status

at a rating of perceived exertion score of 12–14; and (4) flexibility training, including medical gymnastics and Baduanjin, a traditional Chinese exercise. The sessions mentioned above were interdialytic, clinic-based, performed 1 hour per time once per week. Home-based exercises were encouraged 1 hour per day for 3–5 times per week. Thirty-minute walks at normal speed were also advised. In addition, interferential, infrared, and ultrashort wave therapies were applied as pain and anti-inflammatory management of his back, lumbar spine, and bilateral knees.

A dietary plan was made according to his nutritional status. Three regular meals of the following composition were advised [13, 14]: energy, 1450.37 kcal; protein, 40.78 g; fat, 58.92 g; phosphate, 842.1 mg; and potassium, 1343.52 g. Supplementary enteral nutrients were administered as follows: energy, 450 kcal; protein, 15.9 g; and fat, 15.9 g. Water restriction with a weight gain limit of 2 kg was ensured between subsequent dialysis sessions.

The patient was followed-up via telephone for his home-based renal rehabilitation plan every week. The total cost of rehabilitation therapy was approximately 300 RMB (approximately 42 USD) per week. Significant symptom relief was reported after 3 months of rehabilitation, with considerable improvement in appetite, lower limb strength, and concentration. His improvement in QOL corroborated with the increased ability to take on household duties. Changes in all clinical analysis results from baseline are shown in Table 1 and Supplementary Table 1. His serum phosphorus decreased by 22.41%, while inflammatory markers, IL-6 and TNF-α, decreased by 10.07% and 28.05%, respectively. His prealbumin and albumin levels increased by 37.25% and 7.89%, respectively. All lipid profile parameters including serum lipid, triglyceride, cholesterol, and low-density lipoprotein levels increased by > 30%, while all cardiac injury biomarkers including cardiac troponin I, cardiac troponin T, and brain natriuretic peptide decreased by 51.37%, 45.16% and 22.49%, respectively. Stable cardiac hypertrophy was noted based on both end-diastolic and end-systolic left ventricular internal dimensions on echocardiography. While ejection fraction remained unchanged, significant diastolic dysfunction was observed with a decrease in left ventricular end-diastolic pressure-to-left atrial pressure ratio (E/E') from 12 to 8.8. His cardiac output increased from 3 mL/min to 4.2 mL/min. A 5.59%, 5.04%, and 4.76% increase in BMI, fat, and skeletal muscle mass were observed, respectively. His GAD-7 and PHQ-9 scores decreased by 2 and 4 points, respectively. Improvement in physical function was further observed, with increases of 7.62% and 19.3% achieved in grip strength and 6-minute walking distance, respectively. DEI and DPI increased by 48.61% and 38.96%, respectively. His SF-12 QOF score remained stable.

Importantly, his urea reduction ratio and spKt/V increased from 0.730 to 0.765 and 1.54 to 1.71, respectively, as shown in Fig. 1a. Calculations of spKt/V are provided in the Supplementary Material. spKt/V was shown to significantly increase with the level of pre-dialysis urea.

Discussion

The present case suggested that renal rehabilitation with the combination of exercise and nutritional therapy was an effective approach for increasing spKt/V and alleviating uremic syndrome in ESKD.

The concept of renal rehabilitation has seen an increase in recognition due to rising demands for quality of life in CKD patients. However, its practice is limited in China due to the lack of standardized, practicable and economical training programs. Generally, renal rehabilitation may involve exercise and nutritional therapies, medicine, water management, education, as well as psychological and mental support [15]. Exercise interventions should be performed on an individual basis, and are often guided based on RPE [16]. The physiological benefits of exercise in CKD is known to be wide-ranging, and can range from enhancements in aerobic and physical capacity, to improvements in musculoskeletal and cardiovascular function, as well as QOL [17]. Alterations in inflammatory profile, ventricular remodeling, and skeletal muscle anabolic stimulation may be considered potential underlying mechanisms of such benefits [18]. Moreover, the integration of home-based interventions allowed for minimal time spent in clinics, and the ease of adherence. Sufficient nutrition was further ensured to avoid protein catabolism [11].

The dramatic improvement observed in cardiac function, physical performance, and psychological wellbeing, underscoring the complex multiorgan interplay involved in the CKD as a disease. As reported by Yang et al., significant association was demonstrated in new-onset and persistent sarcopenia with cognitive impairment among HD patients [19]. The type IV cardiorenal syndrome also could result in chronic muscle hypoperfusion and metabolic disturbances leading to or aggravating sarcopenia in CKD [20]. The symptoms may not simply come from the uremic syndrome itself, but also COVID-19 which may directly cause clinical complications called "Post-COVID-19 Syndrome" [21]. This syndrome, however, may also recover during this period. Thus, the effect of renal rehabilitation plan may not be fully conclusive, which needs further evidence.

Interestingly, an increase in spKt/V was achieved in our patient following renal rehabilitation. Firstly, the improvement in nutrition status influenced the predialytic urea. Our mathematical model showed the increase in spKt/V is parallel to the increase in predialytic urea. The increase of urea more implies the proper nutritional status rather than adding the concern of increasing small molecule toxins. The HEMO Study found that higher small solute clearance, rather than high membrane flux, contributed to a modest improvement in health-related QOL [22]. Considering the significant improvement in overall condition, the elevation in spKt/V may be thought to play a role in improving dialysis adequacy in this patient. Second, we further propose that dialysis with increased spKt/V increases the clearance of inflammatory mediators, in addition to decreasing their synthetic and metabolic processes. In contrast to intradialytic exercise training which predominantly promote the release of toxins from tissues, interdialytic renal rehabilitation may increase the level of small molecule toxins mainly by increasing synthesis [23]. Altogether, our renal rehabilitation program demonstrated the efficacy in improving health-related QOL by alleviating multi-organ dysfunction, inflammation, and nutritional status. Our case also demonstrated that dialysis adequacy directly related to improvements in spKt/V as a result of nutritional support, as shown in Fig. 1b.

Our case report demonstrated the efficacy of combined clinic- and home-based renal rehabilitation in the management of uremic syndrome in a HD patient. Our study also emphasized the importance of exercise and nutritional therapies in increasing spKt/V and improving the health-related QOL of such patients.

Abbreviations

HD	Hemodialysis
QOL	Quality of life
CKD	Chronic kidney disease
ESKD	End-stage kidney disease
HFpEF	Heart failure with preserved ejection fraction
PHQ-9	9-item Patient Health Questionnaire
GAD-7	7-item Generalized Anxiety Disorder scale
DEI	Daily energy intake
DPI	Daily protein intake

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12882-025-04102-6.

Supplementary Material 1

Supplementary Material 2

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None.

Author contributions

Conceptualization: D.X., W.D. Methodology: C.W. Data collection: L.Y., Q.Z. Writing: D.X. Editing: W.D., J.L. Supervision: W.D. All authors agreed to the published version of the manuscript.

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Data availability

The data generated and analyzed in this case are presented within the manuscript or supplementary information.

Declarations

Ethics approval and consent for publication

This study was conducted according to the guidelines laid down in the Declaration of Helsinki. The authors declare that they have obtained written informed consent from the patient reported in this article, and the consent allowed for their data to be stored, as required by Shanghai Ninth People's Hospital, Shanghai JiaoTong University School of Medicine.

Consent for publication

Written informed consent was obtained from the patient for publication of this case report and any accompanying images. A copy of the written consent is available for review by the Editor of this journal.

Competing interests

The authors declare no competing interests.

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