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Original Article

ORIGINAL ARTICLE

Comparative analysis of hospitalizations among patients treated with hemodialysis and peritoneal dialysis in European pediatric nephrology centers: results from a prospective EPDWG/ESPN Dialysis Working Group study

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ABSTRACT

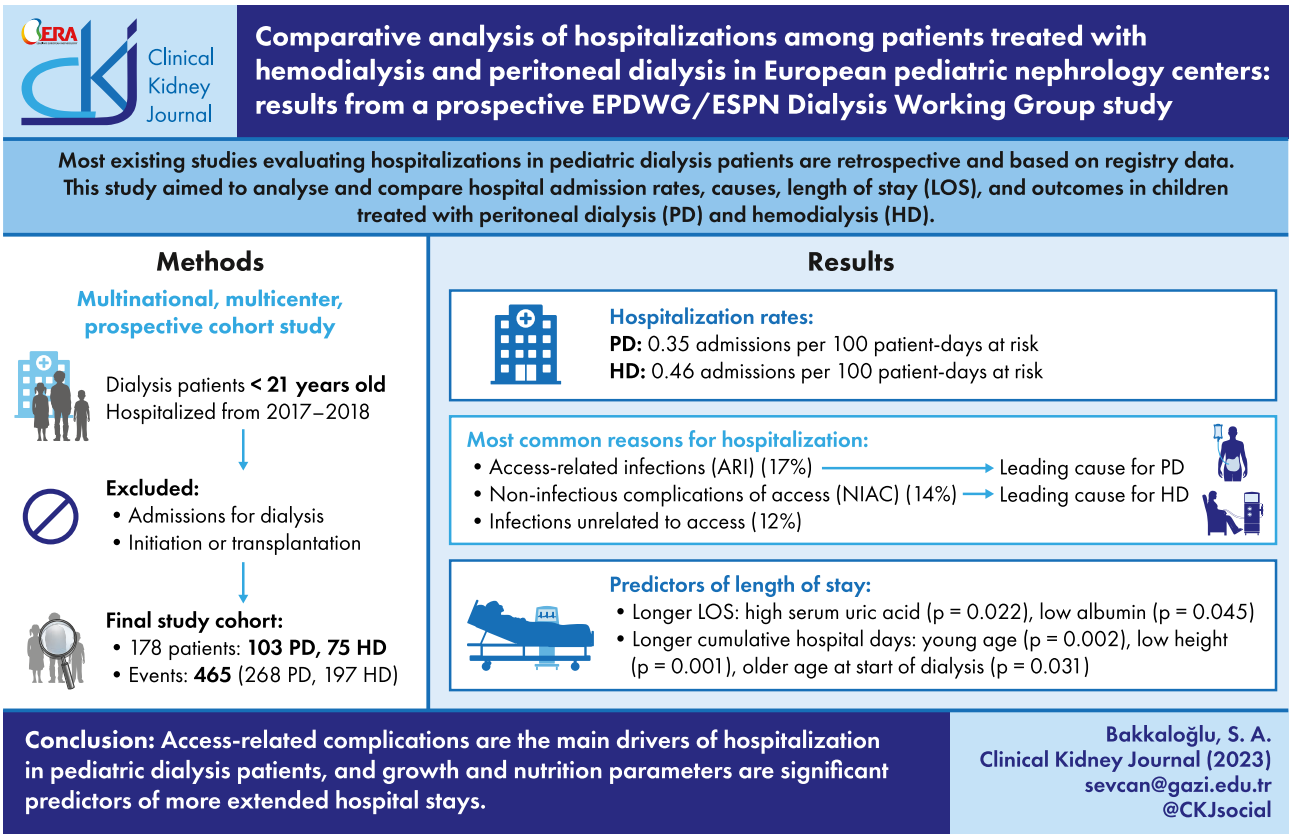
Background and hypothesis. Hospital admissions in pediatric dialysis patients need to be better studied, and most existing studies are retrospective and based on registry data. This study aimed to analyse and compare hospital admission rates, causes, length of stay (LOS), and outcomes in children treated with peritoneal dialysis (PD) and hemodialysis (HD).

Methods. Data from 236 maintenance PD and 138 HD patients across 16 European dialysis centers were collected between 1 July 2017 and 30 June 2018. A total of 178 hospitalized patients (103 PD, 75 HD) were included for further analyses.

Results. There were 465 hospitalization events (268 PD, 197 HD) with a rate of 0.39 admissions per 100 patient-days at risk (PDAR) and 2.4 hospital days per 100 PDAR. The admission rates were not significantly different between HD and PD patients. The most common causes of hospitalization were access-related infections (ARI) (17%), non-infectious complications of access (NIAC) (14%), and infections unrelated to access (12%). ARI was the leading cause in PD patients (24%), while NIAC was more common in HD patients (19%). PD patients had more ARIs, diagnostic procedures, and treatment adjustments ($P < .05$), while HD patients had more NIACs, infections unrelated to access, access placement procedures, and interventional/surgical procedures ($P < .001$). LOS was longer with acute admissions than non-acute admissions ($P < .001$). Overall LOS and LOS in the intensive care unit were similar between HD and PD patients. High serum uric acid and low albumin levels were significant predictors of longer LOS ($P = .022$ and $P = .045$, respectively). Young age, more significant height deficit, and older age at the start of dialysis were predictors of longer cumulative hospital days ($P = .002$, $P = .001$, and $P = .031$, respectively).

Conclusion. Access-related complications are the main drivers of hospitalization in pediatric dialysis patients, and growth and nutrition parameters are significant predictors of more extended hospital stays.

GRAPHICAL ABSTRACT



Keywords: children, hemodialysis, hospitalization, length of stay, peritoneal dialysis

KEY LEARNING POINTS

What was known:

- Most studies evaluating hospital admissions in pediatric dialysis patients are retrospective and based on registry data.

This study adds:

- This study aimed to fill the existing gap in knowledge regarding hospitalizations in the pediatric dialysis population by prospectively analysing and comparing hospital admission rates, causes, LOS, and outcomes of hospitalizations in pediatric PD and HD patients.

Potential impact:

- Access-related complications are the most significant drivers of hospitalization, and growth and nutrition parameters are significant predictors of longer hospital stays. These findings can provide valuable information for healthcare providers and policymakers to identify areas for improvement in pediatric dialysis patient care and develop strategies to reduce hospitalizations.

INTRODUCTION

Hospitalization rates can be viewed as an objective measure of morbidity and quality of life (QoL) among chronic dialysis patients [1–5]. To monitor and improve the quality of care delivered to pediatric dialysis patients, large databases, including the United States Renal Data System (USRDS) (http://www.usrds.org) and the International Pediatric Peritoneal Dialysis Network (IPPN) (http://www.pedpd.org), routinely collect clinical information, including records of hospital admissions, but detailed information is lacking. Children with end-stage kidney disease (ESKD) receiving dialysis are at risk of frequent hospitalizations. In the United States, they are hospitalized approximately one to two times per patient year (PPY) [6]. Children with CKD have 12 times more hospitalizations per 1000 patient-years compared to the general pediatric population [7]. Conflicting results exist regarding hospitalization rates for pediatric peritoneal dialysis (PD) and hemodialysis (HD) patients in prior comparisons [8–10].

Dialysis patients are hospitalized for complications related to CKD and dialysis and other causes [5–7, 11]. An increased risk of hospitalization may result from a high prevalence of co-morbid medical conditions [11], frequently associated with anemia [12], and hypoalbuminemia [13]. Compared with the other disease categories, the average length of stay (LOS) in hospitals is longer in patients with CKD [14, 15]. In order to reduce hospitalization rates and length of hospital stay and improve the QoL of dialysis patients, it is essential to identify and appropriately manage modifiable risk factors. This may include optimizing the management of co-morbid medical conditions and providing comprehensive care and support to address the complex needs of dialysis patients.

Because detailed data on hospitalization in the pediatric dialysis population are scarce, and most previous studies in this patient group were retrospective and created from registry data, by conducting a prospective analysis on hospital admissions, we aimed to obtain more detailed insights into the frequency, rates, reasons, and outcomes of hospitalizations, as well as the length of stay (LOS). Furthermore, by comparing hospitalization data between children on PD and HD we aimed to identify any differences in hospitalization rates and reasons between the two dialysis modalities.

MATERIALS AND METHODS

Data source, design, and the study population

This multinational, multicenter, prospective cohort study collected data from 16 university and tertiary care hospitals treating pediatric dialysis patients in 10 European countries. The healthcare systems in all 16 dialysis centers were public health insurance systems, with no health-related costs incurred by families. The Ethics Committee of Gazi University approved the study protocol as the coordinating center for the study. The study was conducted under the Declaration of Helsinki.

The study included dialysis patients below 21 years of age at the study entry who were admitted between 1 July 2017 and 30 June 2018. Various socio-demographic and clinical measures were recorded for each patient, including age, sex, the primary cause of end-stage kidney disease, anthropometric measurements, dialysis modality and vintage (duration of dialysis), presence of non-renal chronic comorbidities, hypertension, school attendance, and nutrition route. In cases where patients were admitted for peritonitis or PD catheter-related complications, the dialysis modality was presumed to be PD, even if the patient temporarily received HD during that hospitalization.

Assessment of hospital admissions, length of stay, and outcomes

Hospitalization was defined as an admission that included at least one overnight stay. Hospitalizations were recorded from the enrollment date until either the end of the study, the patient underwent kidney transplantation (KTx), was transferred to another hospital, or died, whichever occurred earlier. Study entry was accepted as the start date of the survey for prevalent and date of dialysis initiation for incident dialysis patients. Hospitalizations for dialysis initiation and KTx were not included in the analyses. Hospitalization rates were presented as (i) hospitalizations per 100 patient-days at risk (calculated by dividing the total number of admissions during the observation period by the total number of patient days at risk, multiplied by 100) and (ii) hospital days per 100 patient-days at risk (calculated by dividing the total number of hospital days during the observation period by the number of days at risk multiplied by 100). Days spent in the hospital were excluded from those at risk for the hospitalization rate calculations.

Data collected included:

i. dates of hospital admission and discharge;
ii. type of admission and diagnosis for each hospitalization;
iii. laboratory measures performed on the day of admission and medications;
iv. length of stay (duration of a single episode of hospitalization in days);
v. intensive care unit (ICU) stay;

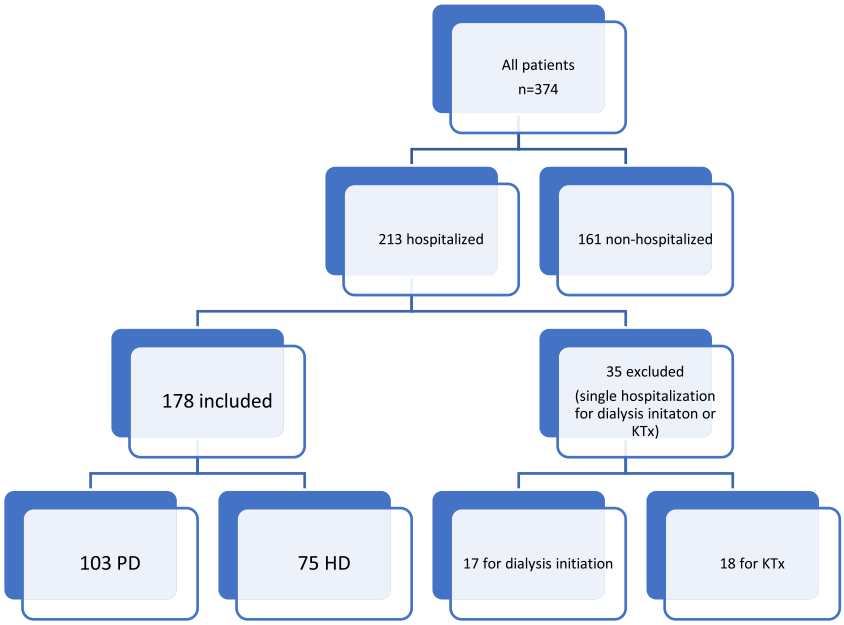


Figure 1: Flow diagram of the patients whose hospital admissions were evaluated. HD: hemodialysis; KTx: kidney transplantation PD: peritoneal dialysis.

vi. additional comorbidity (development of new co-morbid condition during hospitalization); and
vii. outcome (partial or complete recovery, death).

We categorized hospitalization types into four categories (Supplementary Table 1): (i) acute; (ii) necessary; (iii) elective; and (iv) social indication. Acute admissions were considered admissions requiring hospitalization within a few *hours*. Necessary admissions were defined as unscheduled, non-acute, but mandatory admissions requiring hospitalization within a few *days*. Elective admissions included the ones that could be scheduled/planned, i.e. radio-diagnostic testing, elective surgery, and treatment adjustment. The type and causes of hospitalizations were pre-defined, as presented in Table S1 (see online supplementary material). The principal cause was recorded if multiple events occurred in a single hospitalization episode.

Statistical analyses

Statistical analyses were done with SPSS version 23 for Windows (SPSS Inc., Chicago, IL, USA). Categorical variables were presented as frequencies and percentages (proportions), and continuous variables as means with standard deviations (SDs) for the data, which were normally distributed and medians with their interquartile ranges (IQR) from the 25th–75th percentile for those not normally distributed. The chi-square test (Pearson's or Yates's) or Fisher's exact test was used to test the relation between descriptive parameters and categorical variables. The differences between the two independent groups were compared using an independent sample *t*-test (Student's *t*-test) for normally distributed continuous variables or the Mann–Whitney *U* test for non-normally distributed ones. Pearson or Spearman correlation analysis was used when measuring the relationship between continuous variables. Hospitalization rates were also calculated for each patient separately, and median hospitalization rates were also provided. Multivariable linear regression analysis was conducted to examine the influence of factors on LOS in each hospitalization and cumulative LOS. All explanatory variables were tested initially in univariable analysis; variables with a *P*-value lower than .10 were included in the final multivariable model. Statistical significance was defined as a two-tailed *P*-value lower than .05.

RESULTS

Hospitalization rates and frequencies

Overall, during the study period, there were 374 patients on maintenance dialysis, with 138 on HD and 236 on PD. Out of these patients, 213 were hospitalized. Seventeen out of 44 patients hospitalized for dialysis initiation had no subsequent hospitalizations within the study period. Similarly, 18 out of 41 patients who underwent KTx during the study period had no hospitalization before KTX. Therefore, 35 hospitalized patients were excluded from the study, resulting in a final study population of 178 patients (103 PD, 75 HD) (Fig. 1).

During the study period, there were a total of 465 admissions, with 268 from PD patients and 197 from HD patients. The overall rates of hospitalizations were 0.39 admissions per 100 patient-days at risk (PDAR) and 2.4 hospital days per 100 PDAR. For PD patients, the rates were 0.35 admissions and 2.1 hospital days per 100 PDAR, while for HD patients, the rates were 0.46 admissions and 2.9 hospital days per 100 PDAR. The median number of admissions and hospital days per 100 PDAR were 0.8 (IQR:0.6–1.2) admissions and 3 (IQR:1.2–5.8) days for PD patients, and 0.9 [IQR:0.3–1.9] admissions and 3.6 (IQR:1.1–7.4) days for those on HD; the differences between two dialysis modalities were not statistically significant ($P = .19$ and $P = .72$, respectively). More than one-third (35%, $n = 62$) of patients had a single hospitalization, while 70% ($n = 72$) of PD patients and 59% ($n = 44$) of HD patients had multiple hospitalizations ($P = .12$). The maximum hospitalization frequency observed was 10, in two PD patients (Fig. 2).

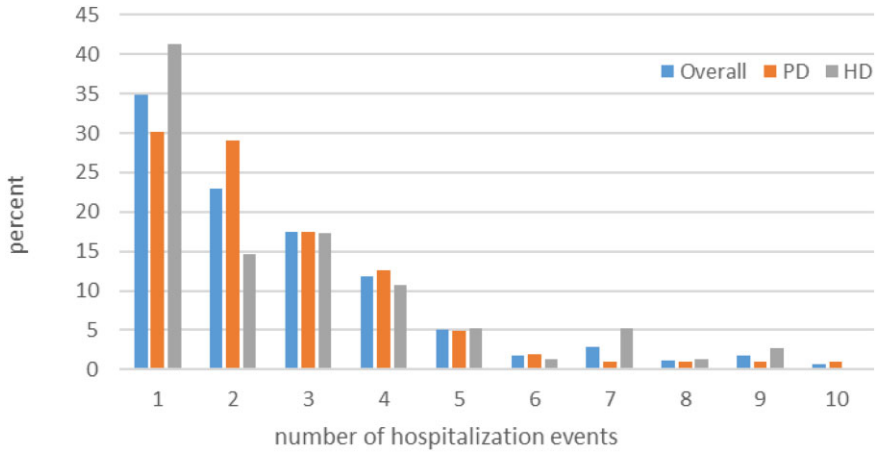


Figure 2: The frequency distribution of hospital admissions overall and by dialysis modality.
HD: hemodialysis; PD: peritoneal dialysis.

Baseline demographic and clinical characteristics of the hospitalized patients

Table 1 describes the baseline demographics and clinical characteristics of the cohort. The cohort's median age was 10.3 (4.9–14.8) years, with 61% ($n = 109$) being male. The median age at dialysis onset was 6.8 (1.4–12.4) years, and the median duration of dialysis was 16 (4–39) months. The primary kidney diseases in 78% of hospitalized patients were congenital anomalies of the kidney and urinary tract (CAKUT), primary glomerular diseases, and inherited kidney diseases. Half (51%, $n = 91$) of the patients had at least one comorbidity at the start of the study, with neurocognitive and/or motor, cardiovascular, and gastrointestinal/hepatobiliary being the most common comorbidities. There were no significant differences between PD and HD patients in terms of sex, weight-, height-, and body mass index (BMI)-standard deviation scores (SDSs), frequency of hypertension (HTN), and primary kidney disease. PD patients were significantly younger at study entry and at the start of dialysis compared to HD patients ($P = .017$ and $P = .013$, respectively). The presence of comorbidity and multimorbidity, and the percentage of patients in each comorbidity category did not differ between PD and HD patients. Residual diuresis was more common in PD than HD patients (52% vs. 23%, $P < .001$), and the enteral feeding (nasogastric tube or gastrostomy) rate was significantly higher in PD patients than HD (35% vs. 19%, $P = .026$). Most HD patients (81%) were undergoing HD via a central venous catheter (CVC).

Reasons for hospitalizations

Two-thirds (62%, $n = 288$) of admissions were classified as acute. While there was no difference between PD and HD patients regarding acute and elective admissions, necessary admissions were more frequent in HD patients compared to PD (24% vs. 15%, $P = .023$). Access-related infections (ARI) (17%), non-infectious complications of access (NIAC) (14%), infections unrelated to dialysis (12%), planned diagnostic tests (11%), and non-infectious complications including fluid overload, hypertension, and electrolyte imbalances (11%) were the five most common causes of hospitalization. The most common procedures were urological interventions and gastrostomy placement/exchange. The respiratory, gastrointestinal, and urinary systems were the most common sites of infectious complications leading to hospitalizations. The leading cause of hospitalization for PD patients was ARI (24%), while for HD patients, it was NIAC (19%). PD patients had more frequent hospitalizations for ARIs, diagnostic procedures, and treatment adjustments. In contrast, HD patients had more frequent hospitalizations for NIACs, access-unrelated infections, VA placement, and interventional or surgical procedures (Table 2).

Length of stay, ICU admissions, and outcomes

Details of LOS, ICU admissions, and outcomes are summarized in Tables 3 and 4. The median LOS was 3 days (IQR: 1–7) in overall hospitalizations (Table 3), and it was significantly longer in acute hospitalizations compared to non-acute ones [3(2–8) vs. 2(1–5) days, $P < .001$]. The reasons for hospitalization requiring the longest median LOS were PD catheter placement for switching from HD to PD, ARI of CVC, and organ/system disorders, respectively (Table 4).

We identified 18 hospitalizations (3.9%) that required ICU care, with the most common reasons being interventional procedures or surgery ($n = 7$), infections unrelated to dialysis access ($n = 6$), fluid electrolyte disorders, and HTN ($n = 3$) (Table 4). The median LOS in the ICU was 6 (IQR: 1–11) days. Hospitalizations, including ICU stays, had longer median LOS [25 (IQR: 15–38) vs 3 (IQR:1–7), $P \leq .001$]. PD and HD patients had similar LOS and ICU stays for both overall and acute admissions.

In order to examine the influence of factors on LOS in each hospitalization and cumulative LOS, explanatory variables with a P-value lower than .10 were included in the multivariable linear regression analysis. High uric acid and low albumin levels were significant predictors of LOS for the overall cohort ($P = .022$ and $P = .045$, respectively) (Table 5). Young age ($P = .002$), older age at the start of dialysis ($P = .031$), and greater height deficit ($P = .001$) were predictors of longer cumulative days at the hospital (Table 5).

As defined by the treating physicians, the complete recovery rates were similar in the admissions of PD and HD patients; however, new comorbidity was observed more frequently in HD patients (5% vs. 0.7%, $P = .005$) (Table 3). Two HD patients (12 and 5 years old, with underlying CAKUT) died during the study period due to intracranial hemorrhage secondary to HTN and multiple comorbidities with sepsis, respectively.

Table 1: Baseline demographic and clinical characteristics of all hospitalized patients and by dialysis modality at study entry.

Demographic and clinical variables	All $n = 178$	PD $n = 103$	HD $n = 75$	P
Age at the start of the survey (years)	10.3 (4.9–14.8)	9.6 (3.7–13.8)	11.7 (6.6–15.2)	.017
Age at the start of dialysis (years)	6.8 (1.4–12.4)	5.8 (0.8–11.8)	8.4 (2.6–14.8)	.013
Time on dialysis (months)	16 (4–39)	18 (5–36)	15.5 (0–40)	.32
Male gender	109 (61%)	62 (60%)	47 (63%)	.73
Anthropometric data				
Weight SDS	−1.67 (−3.08–−0.63)	−1.97 (−3.5–−0.61)	−1.52 (−2.49–−0.71)	.08
Height SDS	−2.17 (−3.46–−0.95)	−2.29 (−3.8–−0.96)	−1.93 (−3.11–−0.95)	.18
BMI (kg/m^2)	16.4 (15.1–19.1)	16 (15–18)	17.5 (15.1–20.2)	.047
BMI SDS	−0.33 (−1.39–0.44)	−0.43 (−1.74–0.56)	−0.24 (−1.19–0.42)	.37
Urine output				
Anuria/Oligo-anuria	106 (60%)	49 (48%)	57 (76%)	<.001
Primary renal disease				1.000[e]
Glomerular	44 (25%)	26 (25%)	18 (24%)	
Primary glomerular diseases	34 (19%)	20 (19%)	14 (19%)	
TMAs (HUS)	7 (4%)	4 (4%)	3 (4%)	
Non-glomerular	134 (75 %)	77 (75%)	56 (76%)	
CAKUT and urologic problems[a]	81 (46%)	42 (41%)	39 (52%)	
Familial/Hereditary renal diseases[b]	23 (13%)	17 (17%)	6 (8%)	
Renovascular diseases	3 (2%)	2 (2%)	1 (1%)	
Other[c]	17 (10%)	9 (9%)	8 (11%)	
Unidentified/Etiology uncertain	13 (7%)	9 (9%)	4 (5%)	
Comorbidity				
Any	91 (51%)	57 (55%)	34 (45%)	.18
Neurocognitive and/or motor	38 (2%)	23 (22%)	15 (20%)	.85
Cardiovascular	25 (14%)	14 (14%)	11 (15%)	1.000
Gastrointestinal/hepatobiliary	23 (13%)	14 (14%)	9 (12%)	.93
Pulmonary/respiratory	21 (12%)	15 (15%)	6 (8%)	.26
Musculoskeletal	17 (10%)	9 (9%)	8 (11%)	.86
Ocular	15 (9%)	10 (10%)	5 (7%)	.65
Genetic (a defined syndrome)	14 (8%)	5 (5%)	9 (12%)	.14
Hemato-oncological	13 (7%)	8 (8%)	5 (7%)	1.000
Endocrinological	10 (6%)	8 (8%)	2 (3%)	.19
Hearing impairment	5 (3%)	4 (4%)	1 (1%)	.39
Immune deficiency	1 (1%)	1 (1%)		
Multimorbidity	50 (28%)	30 (29%)	20 (27%)	.84
Hypertension	88 (49%)	52 (51%)	36 (48%)	.74
Nutrition				.013
Only demand feeding	134 (75%)	70 (68%)	64 (85%)	
Enteral feeding (nasogastric tube or gastrostomy)	44 (25%)	33 (32%)	11 (15%)	
School attendance[d]	94 (78%)	53 (83%)	41 (72%)	.22

Abbreviations: BMI: body mass index; CAKUT: congenital anomalies of the kidney and urinary tract: hemodialysis; HUS: hemolytic uremic syndrome; PD: peritoneal dialysis; TMA: thrombotic microangiopathy.

[a]Including VUR and obstructive uropathies.

[b]Including ciliopathies, hyperoxaluria, Alport syndrome, cystinosis.

[c]Tubulopathies, tubulointerstitial nephritis, nephrolithiasis/nephrocalcinosis, amyloidosis, perinatal asphyxia, metabolic, cardiac and hemato-oncological diseases, post-organ transplantation kidney injury, diabetes mellitus.

[d]Among 121 (64 PD, 57 HD) children aged 6 years and older.

[e]Glomerular vs. non-glomerular.

Values in all columns are presented as mean ± standard deviation or median (interval from the 25th to 75th percentile) for continuous variables, or frequency and percentages (*n*, %) for categorical variables.

Note: Percentages may not be exactly 100% because of rounding.

DISCUSSION

This prospective, multicenter study provides a comprehensive analysis of and valuable insights into hospitalization events, including the rates of admissions, LOS, causes and risk factors for more prolonged hospitalizations, and outcomes in children undergoing maintenance PD and HD in Europe. Throughout the 1-year study period, 465 admissions were recorded, with a rate of 0.39 admissions per 100 PDAR, corresponding to 1.4 admissions per patient per year (PPY) and 2.4 hospital days per 100 PDAR. There were no significant differences in overall hospitalization rates or LOS between children on PD and HD. Complete recovery rates and ICU stays were also similar in the two modalities. However, a notable difference was that HD patients

Table 2: Type of admissions and causes of hospitalizations.

	All hospital admissions $n = 465$	Admissions in PD patients $n = 268$	Admissions in HD patients $n = 197$	P[f]
Type of admission				
Acute	288 (62%)	168 (63%)	120 (61%)	.61
Necessary	88 (19%)	41 (15%)	47 (24%)	.023
Elective	86 (18.4%)	56 (21%)	30 (15%)	.11
Social	3 (0.6%)	2 (0.7%)	1 (0.5%)	1.000
The principal initial diagnosis for hospitalization				
Access infections[a]	78 (16.8%)	65 (24.3%)	13 (6.6%)	<.001
PD-related	65 (14%)	65 (24.3)		
CVC-related	13 (2.8%)		13 (6.6%)	
AVF-related				
Non-infectious complications of access[a]	66 (14.2%)	28 (10.4%)	38 (19.3%)	.010
CVC-related (malposition, catheter dysfunction, thrombotic events)	29 (6.2%)		29 (14.7%)	
PD catheter-related (obstruction to flow, hernia repair)	28 (6%)	28 (10.4%)		
AVF-related	9 (2%)		9 (4.6%)	
Infections[a]	54 (11.6%)	22 (8.2%)	32 (16.2%)	.015
Respiratory	27 (5.8%)	11 (4%)	17 (8.6%)	
Gastrointestinal	9 (2%)	3 (1%)	6 (3%)	
Urinary tract	7 (1.5%)	5 (1.9%)	2 (1%)	
Sepsis	3 (0.6%)	1 (0.4%)	2 (1%)	
Hepatitis	1 (0.2%)		1 (0.5%)	
Unspecified	6 (1.3%)	2 (0.7%)	4 (2%)	
Diagnostic tests[b]	51 (11%)	41 (15.3%)	10 (5.1%)	.001
Noninterventional radiodiagnostic	18 (3.9%)	12 (4.5%)	6 (3%)	
Pretransplant evaluation	17 (3.6%)	13 (4.9%)	4 (2%)	
PET application and/or Kt/V measurement	16 (3.4%)	16 (5.9%)		
Fluid overload, electrolyte imbalances, hypertension[a]	50 (10.8%)	30 (11.2%)	20 (10.2%)	.77
Interventional procedures or surgery[c]	49 (10.5)	20 (7.5%)	29 (14.7%)	.023
Urological	11(2.4%)	4 (1.5%)	7 (3.6%)	
PEG placement/exchange	8 (1.7%)	4 (1.5%)	4 (2%)	
Thoracic	6 (1.3%)	2 (0.7%)	4 (2%)	
Nephrectomy	6 (1.3%)		6 (3%)	
Gastrointestinal and hepatobiliary	5 (1.1%)	2 (0.7%)	3 (1.5%)	
Ophthalmological	4 (0.9%)	4 (1.5%)		
Orthopedic	3 (0.6%)		3 (1.5%)	
Ear-Nose-Throat	1 (0.2%)	1 (0.4%)		
Cardiac	1 (0.2%)	1 (0.4%)		
Obstetric and gynecological	1 (0.2%)		1 (0.5%)	
Other	3 (0.6%)	2 (0.7%)	1 (0.5%)	
Other organ system disorders	47 (10.1%)	28 (10.4%)	19 (9.6%)	.83
Gastrointestinal/hepatobiliary[a]	23 (4.9%)	16 (5.9%)	7 (3.6%)	
Central nervous system[a]	11 (2.4%)	7 (2.6%)	4 (2%)	
Respiratory and pulmonary[b]	7 (1.5%)	2 (0.7%)	5 (2.5%)	
Cardiovascular[a]	3 (0.6%)	3 (1%)		
Obstetric and gynecological[a]	3 (0.6%)		3 (1.5%)	
Treatment schedules	33 (7.1%)	25 (9.3%)	8 (4.1%)	.040
Treatment regulation[d]	15 (3.2%)	12 (4.5%)	3 (1.5%)	
Erythrocyte transfusion[a]	10 (2.1%)	7 (2.6%)	3 (1.5%)	
Infusions (iron, eculizumab, growth hormone, chemotherapy)[d]	8 (1.7%)	6 (2.2%)	2 (1%)	
Access placement/creation	31 (6.7%)	7 (2.6%)	24 (12.2%)	<.001
PD catheter[d,e]	6 (1.3%)[a]		6 (3%)	
Permanent CVC[d]	13 (2.8%)	5 (1.9%)	8 (4%)	
AVF[d]	12 (2.6%)	2 (0.7%)	10 (5%)	
Social reasons	3 (0.6%)	2(0.7%)	1 (0.5%)	
Other (removal of AVF[d], removal of CVC[d], intradialytic hypotension[a])	3 (0.6%)		3 (1.5%)	

Abbreviations: AVF: arteriovenous fistula; CHD: conventional hemodialysis; CVC: central venous catheter; HD: hemodialysis; HDF: hemodiafiltration; ICU: intensive care unit; LOS: length of stay; PD: peritoneal dialysis; SDS: standard deviation score.

[a]Emergent/urgent.

[b]Elective.

[c]16 elective (6 HD,10 PD), 43 necessary (24 HD,19 PD).

[d]Necessary.

[e]Switched from HD.

[f]PD versus HD.

Values in all columns are presented as mean ± standard deviation or median (interval from the 25th to 75th percentile) for continuous variables, or frequency and percentages (*n*, %) for categorical variables.

Note: Percentages may not be exactly 100% because of rounding.

Table 3: Length of hospital stay, ICU admissions, and outcomes.

	All ($n = 465$)	PD ($n = 268$)	HD ($n = 197$)	P[a]
LOS (days)				
Overall	3 (1–7)	3 (2–7)	3 (1–8)	.75
Emergent admissions	3 (2–8)	3.5 (2–9)	3 (1–8)	.37
ICU stay				
Overall	18 (3.9%)	8 (3%)	10 (5.1%)	.50
Emergent admissions	11 (2.4%)	7 (2.6%)	4 (2%)	.76
Days in ICU				
Overall	6 (1–11)	6 (2.5–15)	6.5 (1–11.75)	.68
Emergent admissions	4 (2–19)	3 (2–19)	6.5 (2–49)	.63
Recovery				.13
Complete	410 (88.2%)	242 (90.3%)	168 (85.3%)	
Partial	53 (11.4%)	25 (9.3%)	28 (14.2%)	
New comorbidity	12 (2.6%)	2 (0.7%)	10 (5%)	.005

Abbreviations: HD: hemodialysis; ICU: intensive care unit; LOS: length of stay; PD: peritoneal dialysis.
Values in all columns are presented as median (interval from the 25th to 75th percentile) for continuous variables, or frequency and percentages (*n*, %) for categorical variables.
[a]PD versus HD.
Note: Percentages may not be exactly 100% because of rounding.

Table 4: Length of hospital stay and ICU stay for the most common diagnostic categories.

	LOS (days) median (IQR)	ICU stay n (%)
Access or dialysis-related admissions		
Noninfectious complications of PD	1.5 (1–4.75)	
Infectious complications (ARI) of PD	4 (2–10.25)	
Noninfectious complications of CVC	3 (1–7)	1 (3.4%)
Infectious complications (ARI) of CVC	6 (1–12.25)	
Noninfectious complications of AVF	2 (1–4)	
PD catheter placement (switch from HD to PD)	16 (11–30.5)	
Placement of permanent CVC	2 (1–5.5)	
Creation of AVF	2 (2–2.75)	
Non-access related admissions		
Interventional or surgical procedure	3 (2–10)	7 (12.2%)
Infections	3 (2–7.75)	6 (11.1%)
Fluid-electrolyte disorders and hypertension	4 (2–7)	3 (6%)
Diagnostic tests	2 (1–2)	
Other organ/system disorders	4.5 (1–10.75)	1 (2.1%)
Treatment schedules	2 (1–5)	

Abbreviations: AVF: arteriovenous fistula; CVC: central venous catheter; HD: hemodialysis; ICU: intensive care unit; LOS: length of stay; PD: peritoneal dialysis.
Values in all columns are presented as median (interval from the 25th to 75th percentile) for continuous variables, or frequency and percentages (*n*, %) for categorical variables.
Note: Percentages may not be exactly100% because of rounding.

may be at a higher risk of developing new comorbidities during hospitalization.

Prior comparisons of hospitalization rates for pediatric PD and HD patients have shown conflicting results. The Italian Registry data found that children treated with chronic PD had a higher hospitalization rate than HD [9], while another study from the US showed similar hospitalization rates [8]. The recent USRDS 2020 report also indicated no significant difference in overall hospitalization rates between PD and HD patients (1.7 vs. 1.6 admissions PPY) [10]. In comparison to the USRDS 2020 data [10], our study found a 24% lower admission rate for PD patients (1.3 admissions PPY), while the rates for HD patients were similar (1.7 admissions PPY). Another study conducted by the International Pediatric Peritoneal Dialysis Network (IPPN) [11] reported a median hospitalization rate for PD patients as 1.4 hospital days (IQR:4.7) per 100 PDAR. In our cohort, PD patients showed higher median hospital days per 100 PDAR [3(IQR:1.2–5.8)] than observed in the IPPN study. This difference in hospitalization rates may be explained by the prospective design and non-discretionary reporting of admissions in our study, which enhances the reliability of our data.

Patients on dialysis have an extremely high risk of acute hospitalization relative to the general population [14]. This study also found that patients on dialysis have a high risk of acute hospitalization, with two-thirds of hospitalizations being acute admissions. Remarkably, half were due to access complications, the most frequent cause of overall hospitalizations (31%). ARIs were the leading cause of hospitalization for patients on PD, while non-infectious access complications (NIACs) were the leading cause for those on hemodialysis (HD). In detail, ARIs, diagnostic procedures, and treatment adjustments were statistically more frequent in PD patients and NIACs, and infections unrelated to access, access placement, and interventional or surgical procedures were more common in those on HD.

The USRDS 2015 reports a higher hospitalization rate among incident PD (CAPD) patients than those on HD, mainly due to infectious causes [5]. In an analysis by Lafrance *et al.*, adult PD patients had a higher risk of dialysis access-related hospitalization than HD patients [16]. These data are similar to our results, which show that ARIs were the leading cause of hospitalization in PD patients (14%), 2.3 times higher than hospitalizations due to NIACs (6%). Two previous pediatric reports also align with our results [17, 18]. At the same time, the IPPN registry data showed that mechanical PD catheter-related problems doubled the risk of technique failure compared to infectious causes [19]. Additionally, the Standardizing Care to Improve Outcomes in Pediatric ESKD (SCOPE) collaborative study demonstrated that implementing a standardized follow-up care bundle for PD catheter care resulted in a continued reduction in peritonitis rates from 0.63 episodes per patient-year to 0.42 at three years, and to 0.30 at seven years [20, 21]. Overall, these findings emphasize the need for careful monitoring and management of PD patients, particularly concerning preventing and treating infections and ensuring proper maintenance of PD catheters.

The findings of our study highlight the significant impact of NIACs on hospitalization rates among HD patients. Despite evidence from pediatric studies suggesting the benefits of AVF over CVC, in terms of fewer infections, fewer access changes, and fewer hospitalizations [22], 60–79% of HD patients still have CVC as their vascular access in different series [23–25], and 81% in our cohort. This high prevalence of CVC is concerning, given the increased risk of vascular access dysfunction compared to AVF. In the 552 children of the IPHN Registry, access dysfunction and the need for replacement were twice and thrice more common in children with CVC compared to AVF [23]. In this study, NIACs were three times less common in children with AVF (24%) than those with a CVC (76%). Notably, we did not observe any ARIs among patients undergoing HD via AVF. This highlights the potential benefits of AVF in reducing the risk of infections compared to CVC. Our study also emphasizes the importance of

Table 5: Multiple linear regression analysis results for predicting length of stay and cumulative hospitalization days.

	Unstandardized coefficients		Standardized coefficients		95% CI for B
	B	Std. Error	β	P value	Lower limit—Upper limit
Length of stay					
Uric acid (mg/dL)	0.857	0.366	0.147	.020	0.137–1.578
Albumin (g/dL)	−3.736	1.096	−0.226	.001	−5.895–1.578
Cumulative hospitalization days					
Height SDS	−2.433	0.696	−0.254	.001	−3.806–1.060
Age at study entry (months)	−0.118	0.037	−0.420	.002	−0.192–0.045
Age at dialysis initiation (months)	0.079	0.036	0.295	.031	0.007–0.151

CI: confidence interval.

promoting AVF as the preferred vascular access in HD patients to reduce the risk of NIACs and hospitalizations.

Infections, particularly respiratory infections, accounted for a significant proportion (11.6%) of hospital admissions in our study. The frequency of respiratory infections was two-fold higher in HD patients compared to PD. This may be attributed to closer contact with dialysis staff and other patients in the HD unit and suboptimal vaccination rates against influenza and pneumococcus among dialysis patients, as shown in our earlier work [26]. Efforts should be made to improve vaccination rates among dialysis patients to prevent respiratory infections.

The LOS of individual hospitalizations is considered an essential measure of the severity of illness and underlying patient status [27]. Our findings show that LOS was significantly longer in acute hospitalizations than in non-acute admissions. We found no significant differences between PD and HD hospitalizations in terms of median LOS and days in the ICU. According to the USRDS 2020 report, children receiving PD spent twice as long in the hospital as those receiving HD [10]. Infants under one year old also had a three times longer hospital stay than adolescents aged 13–17 [10]. Furth *et al*. showed that pediatric dialysis patients with severe and moderate growth failure had higher hospitalization rates [28]. In this study, young age and more significant height deficit were independent predictors of longer cumulative LOS. We also found that uric acid and albumin levels were significant predictors of LOS. Higher uric acid levels and lower albumin levels were associated with a longer LOS; the LOS increased by 0.857 days for each mg/dl increase in uric acid and 3.73 days for each gr/dl decrease in albumin. Hypoalbuminemia, either an indicator of malnutrition or inflammation, has been shown to predict survival and hospitalization in pediatric dialysis patients [12, 13] and associated with increased hospital stay and 30-day all-cause mortality in acutely admitted patients [7, 13]. Our findings further emphasize the importance of nutritional support using tube or gastrostomy feeding, particularly in the very young [29, 30]. *In vitro* data showed that uric acid crystallization causes inflammation, obstruction, and fibrosis in the renal tubules and interstitium, leading to the progression of CKD [31–34]. In pediatric HD patients, uric acid was shown to be associated with high BP [35, 36] and, in adult PD patients, high mortality and decreased residual diuresis [37]. Therefore, handling hyperuricemia may be another critical factor in reducing dialysis-related morbidity and hospital days in children on dialysis. In summary, the LOS in hospitalizations for pediatric dialysis patients is influenced by factors such as the type of dialysis, age, height deficit, uric acid levels, and albumin levels. Addressing nutritional support and managing hyperuricemia may help reduce hospital stays and improve outcomes for these patients.

The study's prospective design and the availability of complete hospitalization data for all hospitalized patients are significant strengths of this study. This allows for a comprehensive analysis of hospitalization. However, a limitation of this study is the need for demographic and clinical data on non-hospitalized patients, which prevents a comparison of risk factors between hospitalized and non-hospitalized individuals. In order to address this limitation and better evaluate this issue, future studies could include more detailed information on non-hospitalized patients to gain a more complete understanding of the factors contributing to hospitalization in this population.

In conclusion, this study provides valuable insights into the incidence of hospitalization and the drivers behind it. Access-related reasons were found to be the most significant factors contributing to hospitalization. Additionally, growth and nutrition parameters were identified as predictors of more prolonged hospital stays, highlighting the importance of optimizing nutritional management and dialysis strategies.

SUPPLEMENTARY DATA

Supplementary data are available at *ckj* online.

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AUTHORS' CONTRIBUTIONS

Conception and design were by S.A.B. and Y.Ö.A.; acquisition of data was carried out by S.A.B., Y.Ö.A., C.P.S., E.L., R.S., N.G., I.D., A.S.P., B.Y., F.P., K.V., I.G., N.P., A.Z., I.Z., A.K.B., B.A., M.T., M.S.F., A.Z., A.J., M.E., A.E.; analysis and interpretation of the data were performed by S.A.B. and Y.Ö.A.; and drafting and critical revision of the article for important intellectual content were done by S.A.B., A.E., C.P.S., R.S., and Y.Ö.A.

DATA AVAILABILITY STATEMENT

The data underlying this article can be shared on reasonable request to the corresponding author.

CONFLICT OF INTEREST STATEMENT

S.A.B. is member of the CKJ Editorial Board. The other authors declare no competing conflicts of interest.

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