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ORIGINAL ARTICLE

Recovery of dialysis patients with COVID-19: health outcomes 3 months after diagnosis in ERACODA

Marc H. Hemmelder[1], Marlies Noordzij[2], Priya Vart[2], Luuk B. Hilbrands[3], Kitty J. Jager[4], Alferso C. Abrahams[5], David Arroyo[6], Yuri Battaglia[7], Robert Ekart[8], Francesca Mallamaci[9], Sharon-Rose Malloney[10], Joao Oliveira[11], Andrzej Rydzewski[12], Sivakumar Sridharan[13], Liffert Vogt[14], Raphaël Duivenvoorden[3], Ron T. Gansevoort[2] and Casper F.M. Franssen[2]; ERACODA Collaborators

[1]Department of Internal Medicine, Division of Nephrology, Maastricht University Medical Center, CARIM School for Cardiovascular Disease, University of Maastricht, Maastricht, The Netherlands, [2]Department of Internal Medicine, University Medical Center Groningen, Groningen, The Netherlands, [3]Department of Nephrology, Radboud University Medical Center, Nijmegen, The Netherlands, [4]ERA Registry, Department of Medical Informatics, Amsterdam University Medical Center, University of Amsterdam, Amsterdam Public Health Research Institute, Amsterdam, The Netherlands, [5]Department of Nephrology and Hypertension, University Medical Center Utrecht, Utrecht, The Netherlands, [6]Department of Nephrology, Hospital General Universitario Gregorio Marañón, Madrid, Spain, [7]Department of Specialized Medicine, Division of Nephrology and Dialysis, St. Anna University Hospital, Ferrara, Italy, [8]Department of Dialysis, Clinic for Internal Medicine, University Medical Center Maribor, Maribor, Slovenia, [9]Nephrology, Dialysis and Renal Transplantation Unit, Grande Ospedale Metropolitano di Reggio Cal, Italy, [10]Luzerner Kantonsspital, Luzern, Switzerland, [11]Centrodial (Outpatient Dialysis Center), São João da Madeira, Portugal, [12]Department of Internal Medicine, Nephrology and Transplantation Medicine, Centre of Postgraduate Medical Education, Central Clinical Hospital of the Ministry of Internal Affairs, Warsaw, Poland, [13]Department of nephrology, East and North Hertfordshire NHS Trust, Lister Hospital, Hertfordshire, UK and [14]Department of Internal Medicine, Section of Nephrology, Amsterdam University Medical Centers, Amsterdam Cardiovascular Sciences, University of Amsterdam, Amsterdam, The Netherlands

Correspondence to: Marc H. Hemmelder; E-mail: marc.hemmelder@mumc.nl

ABSTRACT

Background. Coronavirus disease 2019 (COVID-19)-related short-term mortality is high in dialysis patients, but longer-term outcomes are largely unknown. We therefore assessed patient recovery in a large cohort of dialysis patients 3 months after their COVID-19 diagnosis.

Methods. We analyzed data on dialysis patients diagnosed with COVID-19 from 1 February 2020 to 31 March 2021 from the European Renal Association COVID-19 Database (ERACODA). The outcomes studied were patient survival, residence and functional and mental health status (estimated by their treating physician) 3 months after COVID-19 diagnosis. Complete follow-up data were available for 854 surviving patients. Patient characteristics associated with recovery were analyzed using logistic regression.

Results. In 2449 hemodialysis patients (mean ± SD age 67.5 ± 14.4 years, 62% male), survival probabilities at 3 months after COVID-19 diagnosis were 90% for nonhospitalized patients ($n = 1087$), 73% for patients admitted to the hospital but not to an intensive care unit (ICU) ($n = 1165$) and 40% for those admitted to an ICU ($n = 197$). Patient survival hardly decreased between 28 days and 3 months after COVID-19 diagnosis. At 3 months, 87% functioned at their pre-existent functional and 94% at their pre-existent mental level. Only few of the surviving patients were still admitted to the hospital (0.8–6.3%) or a nursing home (∼5%). A higher age and frailty score at presentation and ICU admission were associated with worse functional outcome.

Conclusions. Mortality between 28 days and 3 months after COVID-19 diagnosis was low and the majority of patients who survived COVID-19 recovered to their pre-existent functional and mental health level at 3 months after diagnosis.

Keywords: COVID-19, dialysis, functional health status, mental health status, survival

INTRODUCTION

The COVID-19 pandemic has had a major impact around the world, with dialysis patients being among the patient groups with the highest mortality [1, 2]. If infected with severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), these patients often develop a serious course of COVID-19, which requires in-hospital care. The European Renal Association COVID-19 Database (ERACODA) Working Group previously

KEY LEARNING POINTS

What is already known about this subject?

- Previous studies have shown that coronavirus disease 2019 (COVID-19)-related short-term mortality is high in dialysis patients.
- Data on the longer-term recovery of dialysis patients after COVID-19 are scarce.
- We therefore studied different health outcomes, including patient survival, residence (home/hospital/nursing home) and functional and mental health status in a large group of dialysis patients 3 months after a COVID-19 diagnosis.

What this study adds?

- This study demonstrates that 78% of the dialysis patients survived COVID-19, with the large majority recovering to their pre-existent functional and mental health level at 3 months after diagnosis. Patients who had not yet recovered were mostly those who had been admitted to the intensive care unit (ICU).

What impact this may have on practice or policy?

- Our findings show that if dialysis patients survive COVID-19, the outcome at 3 months is rather good. This implies that optimal treatment of COVID-19 in this high-risk group is recommended without restrictions. Treating physicians may use this information during consultation with patients, for instance, when in doubt whether to admit them to the hospital and/or an ICU.

reported a 28-day mortality of 25% in dialysis patients during the first pandemic wave [3]. In these patients, age and frailty were the dominant factors independently associated with higher mortality [3]. These findings were confirmed in larger cohorts of patients receiving dialysis [4–6].

Notwithstanding the high short-term mortality in dialysis patients, most patients were alive at 28 days after the diagnosis of COVID-19, but data on longer-term health outcomes in dialysis patients who survived COVID-19 are virtually absent. It could well be that a relevant portion of patients experience functional deterioration without recovery or die at a later stage due to the long-term complications of COVID-19 [7]. The aim of this study was to assess the recovery of dialysis patients at 3 months after COVID-19 diagnosis, in terms of patient survival, residence and functional and mental health status. Here we present the first results on these outcomes, as well as their associations with patient and COVID-19 characteristics.

MATERIALS AND METHODS

Study population

This study is based on data from ERACODA, which contains granular data on adult patients (>18 years of age) with kidney failure who were treated with dialysis or living with a functioning kidney allograft and who developed COVID-19 [8]. The COVID-19 diagnosis was based on a positive result on a real-time polymerase chain reaction (PCR) assay or a rapid antigen test of nasal and/or pharyngeal swab specimens and/or compatible findings on a computed tomography (CT) scan or chest X-ray of the lungs.

The database uses REDCap software, a secure web application for building and managing online databases (Research Electronic Data Capture, Vanderbilt University Medical Center, Nashville, TN, USA) [9] and is hosted at the University Medical Center Groningen (UMCG), Groningen, The Netherlands. Patient information is stored pseudonymized. The study was approved by the institutional review board of the UMCG, who deemed the collection and analysis of data exempt from ethics review according to the Medical Research Involving Human Subjects Act (WMO). Data on outpatients and hospitalized patients were voluntarily reported by physicians responsible for their care.

A total of 225 physicians from 141 centers in 33 countries, mostly in Europe and bordering the Mediterranean Sea, entered data in ERACODA. For the current study, we included all dialysis patients who presented with COVID-19 between 1 February 2020 and 31 March 2021 for whom information on age, sex, hospitalization, ICU admission and 3-month vital status were available. The inclusion started at the start of the COVID-19 pandemic in Europe with the predominant original SARS-CoV-2 genotype and ended when the effect of the vaccination campaign in Europe became of influence. For 80 patients (3.3%), the dialysis modality was unknown, and we assumed that these patients received in-center hemodialysis (HD), because this was by far the most common dialysis modality in ERACODA and also in general within Europe [10].

Data collection

We collected detailed information on patient characteristics, including age, sex, ethnicity, frailty, comorbidities, hospitalization and medication use and on COVID-19-related characteristics such as symptoms, vital signs and laboratory test results. Frailty was assessed using the Clinical Frailty Score [11], which ranges from 1, representing very fit, to 9, representing terminally ill. Comorbidities were recorded at presentation from patient charts and obesity was defined as a body mass index (BMI) >30 kg/m^2.

Information on functional and mental health outcomes was collected once at 3 months after first presentation with COVID-19. Due to the study design, we had no options to invite individual patients to report on their functional and mental outcomes. Since nephrologists generally meet their HD patients every week and know their patients well, we asked them to report on these outcomes. We composed a standardized questionnaire for this purpose (Appendix 1). If patients had not recovered at 3 months, we asked which limiting factors were judged to be responsible for not reaching the pre-COVID-19 functional and mental health status and how long they estimated the interval to reach the pre-COVID-19 status.

Statistical analysis

All baseline patient and disease characteristics are presented for the total population and separately for the categories not hospitalized, hospitalized but not ICU admitted and hospitalized and ICU admitted. Continuous data are presented as mean [standard deviation (SD)] or median [interquartile range (IQR)] if the data were not normally distributed. Categorical data are presented as percentages. We used analysis of variance (ANOVA) tests to compare continuous variables between the three subgroups (Kruskal–Wallis test for non-normally distributed data) and Pearson chi-squared tests to compare categorical variables. HD and peritoneal dialysis (PD) patients were analyzed separately, but the main focus in this article is on HD, because of the small sample size of the PD group.

Unadjusted cumulative survival probability curves by hospitalization and ICU admission status were created using the Kaplan–Meier method and compared using log-rank tests. Unadjusted and adjusted hazard ratios (HRs) with 95% confidence intervals (CIs) were calculated to compare the risk of mortality in HD and PD patients.

We analyzed functional and mental health outcomes in those who were alive at 3 months after a COVID-19 diagnosis. Numbers and proportions are presented for the total group and by hospital and ICU admission status. The Pearson chi-squared test was used to compare proportions between patient groups.

Unadjusted and adjusted logistic regression models were applied to calculate odds ratios (ORs) with 95% CIs for the likelihood of reaching the pre-COVID-19 functional or mental health status. A broad set of variables, including demographics, comorbidities, COVID-19 symptoms and admission to hospital and/or ICU, was included in the crude analysis. Selection of variables for the multivariable model was based on statistical significance in the crude analysis. The multivariable models included age, sex, frailty score, heart failure, respiration rate, shortness of breath, hospitalization and ICU admission for functional status and all these variables plus coronary artery disease for mental health status. Missing data in the multivariable models were handled by multiple imputations (10 imputed datasets created with 100 interactions) with the chained equations method using all variables included in the model [12, 13].

All analyses were performed using Stata version 14.0 (StataCorp, College Station, TX, USA). A two-sided P-value <0.05 indicated statistical significance.

RESULTS

Study population and patient characteristics

During the study period, 3331 dialysis patients in the ERACODA database presented with COVID-19. Information on age, sex, hospitalization, ICU admission and 3-month vital status was available for 2617 patients (2449 HD and 168 PD). There were 1087 HD patients (44%) who were not hospitalized, 1165 (48%) who were hospitalized but not admitted to the ICU and 197 (8%) who were admitted to the ICU. Table 1 shows the baseline patient and disease characteristics for these subgroups and for the total group. For almost all patients (99.8%) the COVID-19 diagnosis was based on a positive PCR test. Patients who were admitted to the ICU were younger, less often Caucasian, less frail and had higher BMI, longer dialysis vintage, fewer previous transplantations and more severe COVID-19 symptoms compared with the two other subgroups. Characteristics of PD patients are presented in Supplementary data, Table S1.

Survival at 3 months

Overall, 1909 of the 2449 HD patients (78%) survived the first 3 months after presentation with COVID-19. Those who survived were younger, had a lower frailty score, fewer comorbid conditions and fewer symptoms and signs of COVID-19 at presentation than those who died in the first 3 months (Supplementary data, Table S2).

At day 28, the survival probability of HD patients was 90% in the patients who were not hospitalized, 75% in those who were hospitalized but not admitted to the ICU and 47% in those who were admitted to the ICU. At 3 months after a COVID-19 diagnosis, survival probabilities were 90%, 73% and 40%, respectively. This indicates that there is a limited effect on survival between 28 days and 3 months after diagnosis. Survival was lower in patients admitted to the ICU when compared with those who were not (P-value log-rank test <0.0001). Kaplan–Meier curves for the three groups are presented in Figure 1.

Among PD patients, survival probabilities at 3 months were 86% for patients not hospitalized, 61% for patients hospitalized but not admitted to the ICU and 67% for those admitted to the ICU (Supplementary data, Figure S1). The survival probability was lower ($P = 0.006$) in those who were hospitalized but not admitted to the ICU compared with those admitted to the ICU.

Residence at 3 months

Figure 2 presents the residence of survivors at 3 months after the COVID-19 diagnosis. Although this variable was unknown for a relatively large proportion of patients (58% of patients who were not admitted, 27% of those hospitalized and 28% of those admitted to the ICU), we observed that in cases where residence was known, most patients were at home at 3 months of follow-up (36%, 65% and 61%, respectively). Approximately 5% of the patients (in all three groups) lived in a nursing home, whereas the proportion of patients who were in the hospital varied between 0.8% in those who were initially not hospitalized and 6.3% in patients who had been admitted to the ICU.

Table 1. Baseline demographic and clinical characteristics of HD patients with COVID-19 by hospitalization and ICU admission status

Variable	Total[*] ($n = 2449$)	Not hospitalized ($n = 1087$)	Hospitalized, no ICU ($n = 1165$)	Hospitalized, ICU ($n = 197$)	P-value
Patient characteristics					
Male sex, *n*(%)	1509 (62)	645 (59)	740 (64)	124 (63)	0.12
Age (years), mean ± SD	67.5 ± 14.4	67.4 ± 15.1	68.0 ± 13.9	65.0 ± 12.5	0.03
BMI (kg/m^2), mean ± SD	26.6 ± 5.5	26.9 ± 5.8	26.3 ± 5.4	27.0 ± 5.2	0.05
Race, *n* (%)					0.006
White or Caucasian	1976 (85)	850 (86)	976 (85)	150 (77)	
Non-white	357 (15)	141 (14)	171 (15)	45 (23)	
Tobacco use, *n*(%)					<0.001
Current	158 (6.5)	42 (3.9)	100 (8.6)	16 (8.1)	
Prior	459 (19)	139 (13)	270 (23)	50 (25)	
Never	879 (36)	269 (25)	519 (45)	91 (46)	
Unknown	953 (39)	637 (59)	276 (24)	40 (20)	
Clinical frailty scale (AU), mean ± SD	4.0 ± 1.8	3.9 ± 1.8	4.1 ± 1.9	3.8 ± 1.5	0.04
Reason for screening, *n*(%)					<0.001
Symptoms only	1132 (62)	295 (51)	707 (66)	130 (68)	
Symptoms and contact	280 (15)	59 (10)	175 (16)	46 (24)	
Contact only	218 (12)	110 (19)	103 (9.3)	5 (2.6)	
Routine screening	207 (11)	110 (19)	88 (8.2)	9 (4.7)	
COVID-19 diagnosis, *n*(%)					
Positive PCR	2383 (99.8)	1079 (99.8)	1113 (99.7)	191 (100)	0.94
Abnormal X-ray[a]	562 (60)	39 (80)	434 (64)	89 (78)	<0.001
Abnormal CT scan[b]	475 (81)	23 (47)	353 (82)	99 (88)	<0.001
Comorbidities, *n*(%)					
Obesity	464 (23)	203 (24)	215 (21)	46 (26)	0.25
Hypertension	1979 (81)	836 (77)	986 (85)	157 (80)	<0.001
Diabetes mellitus	1046 (43)	409 (38)	542 (47)	95 (48)	<0.001
Coronary artery disease	825 (34)	325 (30)	425 (36)	75 (38)	0.002
Heart failure	571 (23)	200 (18)	321 (28)	50 (25)	<0.001
Chronic lung disease	317 (13)	107 (10)	178 (15)	32 (16)	<0.001
Active malignancy	136 (5.6)	44 (4.1)	82 (7.0)	10 (5.1)	0.008
Auto-immune disease	88 (3.6)	27 (2.5)	54 (4.6)	7 (3.6)	0.02
Primary kidney disease, *n*(%)					
Primary glomerulonephritis	308 (13)	112 (11)	165 (14)	31 (16)	0.06
Pyelonephritis	37 (1.6)	16 (1.6)	20 (1.7)	1 (0.5)	0.44
Interstitial nephritis	69 (3.0)	31 (3.1)	34 (3.0)	4 (2.0)	0.71
Hereditary kidney disease	160 (6.7)	87 (8.8)	63 (5.5)	10 (5.1)	0.006
Congenital diseases	33 (1.4)	18 (1.8)	14 (1.2)	1 (0.5)	0.27
Vascular diseases	420 (18)	214 (22)	174 (15)	32 (16)	<0.001
Secondary glomerular diseases	200 (8.6)	131 (13)	60 (5.2)	9 (4.6)	<0.001
Diabetic kidney disease	542 (23)	153 (16)	322 (28)	67 (34)	<0.001
Other	378 (16)	166 (17)	187 (16)	25 (13)	0.37
Unknown	184 (7.9)	59 (6.0)	109 (9.5)	16 (8.2)	0.01
HD modality, *n*(%)					0.03
Centre HD	2290 (99)	975 (98)	1122 (99)	193 (99)	
Home HD	28 (1)	19 (1.9)	8 (0.7)	1 (0.5)	
Dialysis vintage (years), median (IQR)	4 (2–8)	4 (2–8)	4 (2–8)	5 (3–9)	0.07
Previous kidney transplantation, *n* (%)	195 (8.6)	105 (10.9)	79 (7.0)	11 (5.7)	0.002
Medication use, *n*(%)					
RAAS inhibition	503 (27)	185 (32)	269 (25)	49 (27)	0.01
Immunosuppressive					
Prednisone	126 (5.1)	37 (3.2)	79 (6.8)	10 (5.1)	0.027
Tacrolimus	33 (1.3)	17 (1.6)	14 (1.2)	2 (1.0)	0.05
Mycophenolate	16 (0.7)	7 (0.6)	8 (0.7)	1 (0.5)	0.66
COVID-19-related characteristics					
Presenting symptoms, *n* (%)					
Sore throat	252 (14)	73 (12)	141 (13)	38 (22)	0.004
Cough	920 (47)	222 (36)	574 (50)	124 (66)	<0.001
Shortness of breath	621 (32)	73 (12)	423 (37)	125 (65)	<0.001
Fever	1067 (54)	218 (36)	698 (60)	151 (77)	<0.001
Headache	193 (10)	51 (8.7)	114 (10)	28 (16)	0.014
Nausea or vomiting	184 (9.5)	39 (6.5)	119 (10)	26 (14)	0.003
Diarrhea	236 (12)	60 (9.9)	146 (13)	30 (16)	0.05
Myalgia or arthralgia	404 (22)	85 (14)	267 (24)	52 (30)	<0.001

Table 1. Continued

Variable	Total (*n* = 2449)	Not hospitalized (*n* = 1087)	Hospitalized, no ICU (*n* = 1165)	Hospitalized, ICU (*n* = 197)	P-value
Vital signs, mean ± SD					
Temperature (°C)	37.4 ± 1.0	37.0 ± 1.0	37.5 ± 1.0	37.8 ± 1.0	<0.001
Respiration rate/min	18.4 ± 4.9	15.9 ± 3.7	19.1 ± 4.8	21.3 ± 5.3	<0.001
O_2 saturation room air (%)	93.9 ± 5.4	96.6 ± 2.7	93.5 ± 5.2	90.0 ± 7.8	<0.001
Systolic BP (mmHg)	136.4 ± 25.4	139.4 ± 24.9	136.0 ± 25.5	130.8 ± 25.2	<0.001
Diastolic BP (mmHg)	73.6 ± 15.1	72.5 ± 14.9	73.9 ± 15.5	75.4 ± 13.6	0.08
Pulse rate (BPM)	81.1 ± 15.0	75.8 ± 13.0	82.6 ± 15.3	86.9 ± 14.0	<0.001
Laboratory test results, median (IQR)					
Lymphocytes (×1000/μL)	0.9 (0.6–1.3)	0.9 (0.7–1.2)	0.9 (0.6–1.4)	0.7 (0.5–1.1)	0.0013
CRP (mg/L)	41 (9.9–94)	5 (3–30)	43 (12–95)	71 (24–124)	<0.001
Hospitalization duration (days)	14 (8–23)	–	14 (8–21)	24 (18–40)	<0.001
ICU admission duration (days)	6 (2–11)	–	–	6 (2–11)	–

*Numbers may not add up to total because of missing values.

[a]X-rays were performed for 933 of 2449 patients (38%), including 138 in the non-hospitalized group, 681 in the group admitted to the hospital (not ICU) and 114 in patients admitted to the ICU.

[b]CT scans were performed for 589 of 2449 patients (24%), including 49 in the non-hospitalized group, 428 in the group admitted to the hospital (not ICU) and 112 in patients admitted to the ICU.

Groups were compared using one-way ANOVA, Kruskal–Wallis test or chi-squared test, as appropriate. Obesity is defined as BMI >30 kg/m^2.

RAAS, renin-angiotensin-aldosterone system; BP, blood pressure; CRP, C-reactive protein; O_2, oxygen.

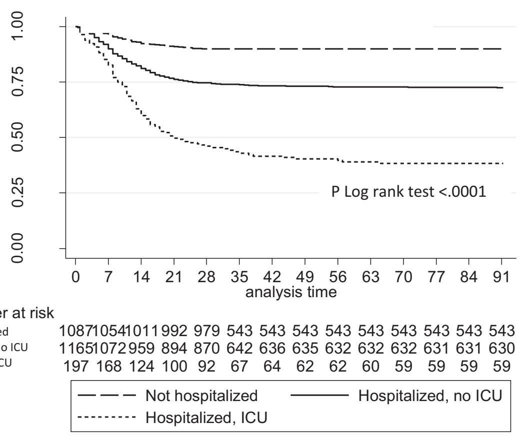

FIGURE 1: Kaplan–Meier curves presenting cumulative 3-month survival probability (in days) among HD patients with COVID-19.

Functional and mental health status

Data on functional and mental health status were collected at 3 months after a COVID-19 diagnosis and were available for 854 of the 1014 HD patients (84%) who were alive at this time point and had follow-up data available (Supplementary data, Figure S2). The residence status of these patients is presented in Supplementary data, Figure S3. Characteristics of patients who were excluded from this analysis because of missing values did not differ from those of the included patients, except for active malignancy as a comorbidity, which was more frequent in patients with missing data, and respiration rate, which was lower in those with missing data (Supplementary data, Table S3).

At 3 months after a COVID-19 diagnosis, according to their nephrologist, functional status had recovered to the pre-COVID-19 level in 87% of the patients (Figure 3A), whereas this was not the case in 111 patients (13%). The proportion of patients who did not recover was higher in the subgroup admitted to the ICU compared with the other two subgroups. Among those who had not yet recovered, the most important limiting factors were reduced muscle strength (48%), reduced mobility (41%) and tiredness (37%). For 58% of these patients, their nephrologist estimated that they would reach their pre-COVID-19 functional status within 1 year after diagnosis, while they estimated that this would never happen in 28%. Patients for whom a late (>1 year) or no functional recovery was expected, were older, had a higher frailty score, more often had coronary artery disease as a comorbidity and had a lower oxygen saturation (data not shown). There were no statistically significant differences in limiting factors for recovery between patients who were not hospitalized, those hospitalized but not admitted to the ICU and those admitted to the ICU (Table 2). In a multivariable logistic regression analysis, older age [OR 0.98/year (95% CI 0.97–1.0)], higher frailty score [OR 0.79/unit (95% CI 0.70–0.90)] and ICU admission [OR 0.43 (95% CI 0.18–0.99)] were associated with a lower likelihood to reach pre-COVID-19 functional status (Table 4).

Treating nephrologists indicated that 94% of their patients had reached their pre-COVID-19 mental health status at 3 months after COVID-19 diagnosis (Figure 3B). Although mental health tended to be more often impaired in the subgroup of patients admitted to the ICU, this was not statistically different compared with the other two subgroups. Among the 51 patients (6%) who had not reached their pre-COVID-19 mental health status, the most commonly mentioned limiting factors were memory loss (35%), depression (31%) and anxiety (18%). For 56% of these patients, their nephrologist expected that the pre-COVID-19 mental status would be reached within the upcoming year, whereas 27% were expected to never fully recover their mental health state. There were no statistically significant differences between the subgroups based on hospital admission (Table 3). For mental health status, only a higher frailty score [OR 0.75/unit (95% CI 0.63–0.90)]

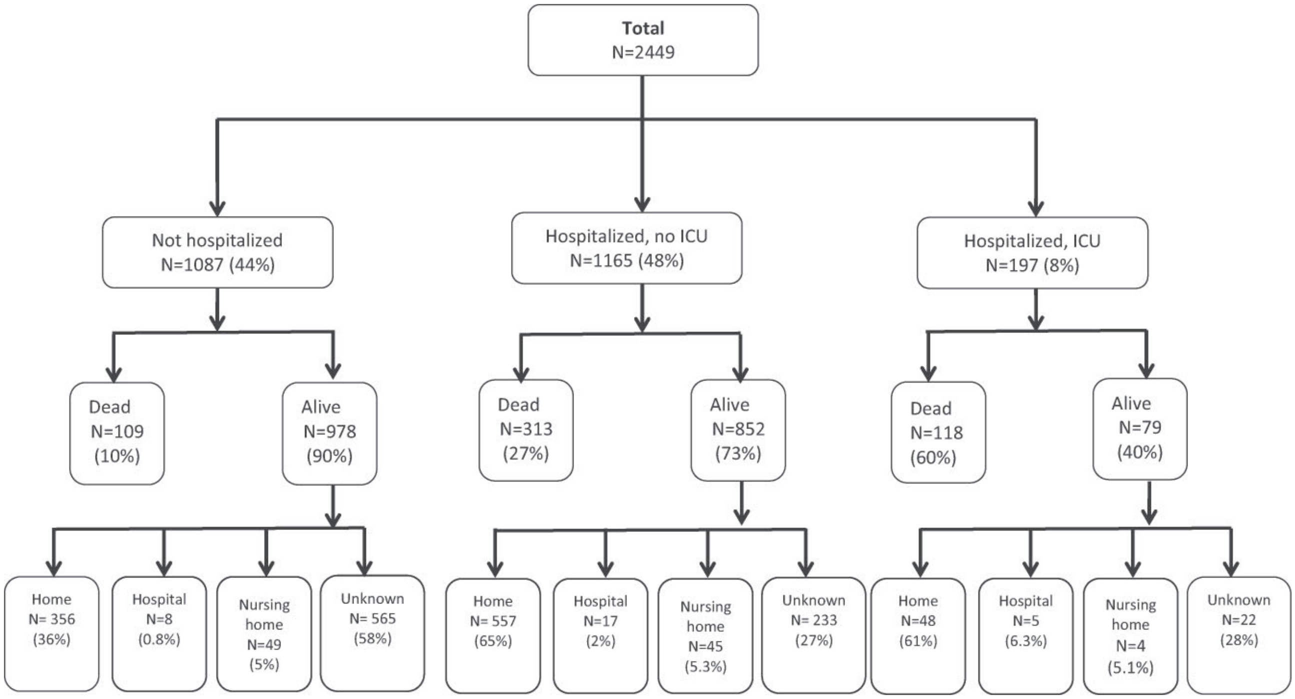

FIGURE 2: Flow diagram of hospitalization, ICU admission, vital status and residence at 3 months after a COVID-19 diagnosis.

was associated with a lower likelihood of reaching the pre-COVID-19 status (Table 4).

There was considerable overlap in the recovery of functional and mental status. Among the 743 patients in whom the functional status had recovered within 3 months, there were only 5 patients (0.67%) in whom the mental status had not yet recovered. Conversely, almost half [46 (41.4%)] of the 111 patients who had not yet recovered functionally also had not recovered mentally after 3 months.

Finally, the residence status differed between patients who had and those who had not yet recovered. Among those whose functional status had not recovered, 17.2% lived in a nursing home and 11.8% were still hospitalized after 3 months versus 9.6% and 1.8%, respectively, in those who had recovered. For mental status, 24% of those not recovered lived in a nursing home and 20% were still hospitalized, whereas this was 9.7% and 2%, respectively, for those who had reached their pre-COVID-19 mental status.

In the subgroup of PD patients, data on functional and mental health status were available in 52 of the 168 patients. At 3 months, 42 PD patients (81%) had reached their pre-COVID-19 functional status and 46 (88%) had reached their pre-COVID-19 mental health status. The small numbers of patients who did not reach their previous functional ($n = 10$) and mental health ($n = 6$) status precluded a meaningful analysis of the time needed to recover and factors that limited recovery in this group.

DISCUSSION

This study shows that functional and mental health had recovered to the pre-existent level according to their nephrologists in the majority of dialysis patients who were alive at 3 months after a COVID-19 diagnosis. Impaired functional outcome was associated with older age, higher frailty score and ICU admission, whereas impaired mental outcome was associated only with higher frailty score. Among those who had not fully recovered at 3 months after a COVID-19 diagnosis, 58% of patients were expected to recover functionally and 56% to recover mentally within 1 year. Together, our results show that although the short-term mortality of COVID-19 in HD patients is high, surviving patients have a good prognosis to recover from COVID-19, both functionally and mentally.

We demonstrated that in dialysis patients who were alive at 3 months after a COVID-19 diagnosis, only 13% still had an impaired functional status compared with their pre-COVID-19 status. Not unexpectedly, nonrecovery to pre-COVID-19 functional status was more frequent in patients who were admitted to the ICU. The most prevalent limiting factors for functional recovery were reduced muscle strength (48%), reduced mobility (41%) and tiredness (37%). In a French general population cohort, 51% of patients who were admitted for COVID-19 reported in a telephone interview to have at least one persistent symptom, of which 31% had fatigue [14]. In a study from China, patients who survived COVID-19 were interviewed after hospital admission with a series of questionnaires [15]. Fatigue or muscle weakness was reported by as many as 63% of patients 6 months after COVID-19 onset. A report from Italy demonstrated that 54% of COVID-19 survivors had some form of functional impairment after hospital admission as measured by a short physical performance battery and 2-minute walking test [16]. The frequency of nonrecovery of functional health after surviving COVID-19 seems less distinct in our dialysis cohort. The difference in findings may be explained, at least in part, by the fact that dialysis patients are already adapted to having limited

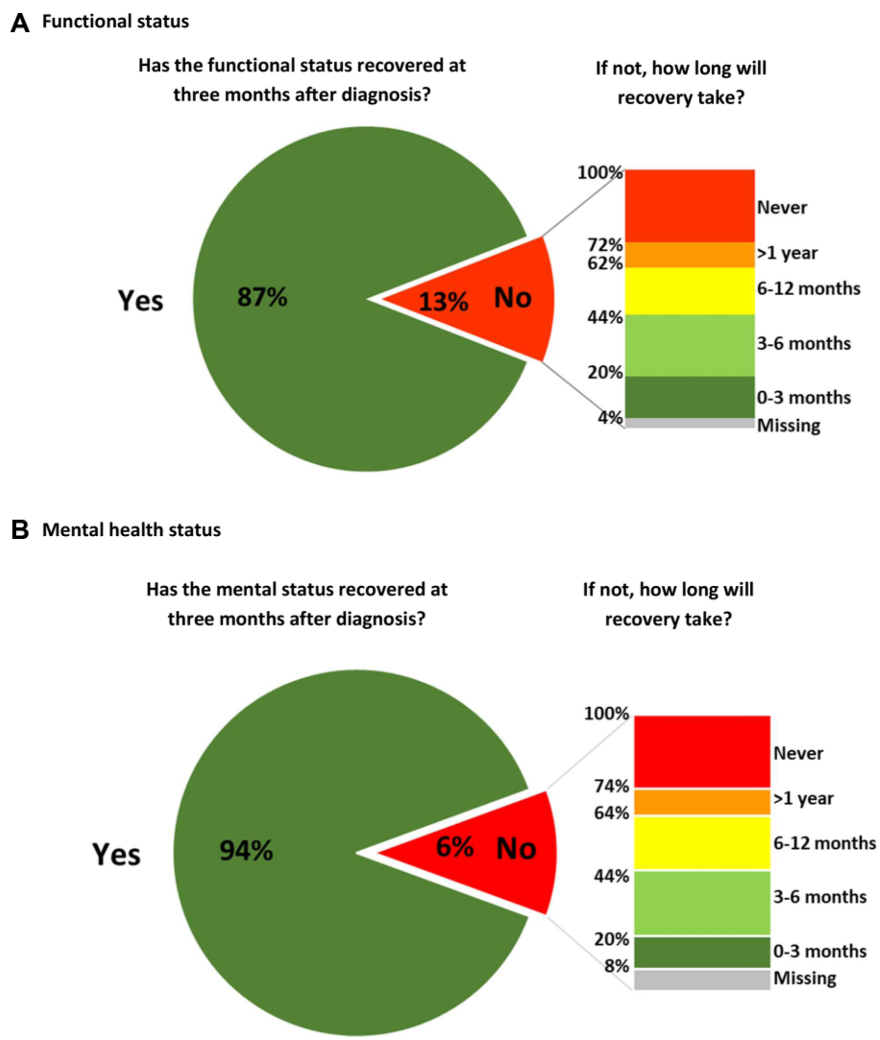

FIGURE 3: Functional and mental health status in HD patients at 3 months after a COVID-19 diagnosis, as judged by the treating nephrologist.

pre-existent functional capacity. [17]. In addition, mortality is high in these patients, which may also lead to the most fit patients surviving. Lastly, differences between these previous studies and our study in the way of assessing functional status may have played a role.

Notably, the COVID-19 pandemic has raised levels of anxiety and depression in the general population and in patients with various chronic conditions [18–21]. In contrast, Bonenkamp *et al.* [22] showed that the mental health of a small group of chronic dialysis patients without a diagnosis of COVID-19 was not affected during the pandemic as measured by the mental component summary score of Short Form 12 and items of the Dialysis Symptom Index. This suggests that the dialysis population may be different from other populations with respect to the impact of the COVID-19 pandemic on mental health, maybe because patients already suffer greatly from their kidney disease and treatment [23]. Many dialysis patients have developed coping mechanisms in order to maintain satisfactory mental health. In a French cohort of COVID-19 survivors from the general population, 21% of patients reported cognitive disturbances 4 months after a COVID-19 diagnosis [14]. In a Chinese cohort of COVID-19 survivors from the general population, sleep difficulties and anxiety or depression were reported by 26% and 23% of patients, respectively [15]. No other data have previously been published on the recovery of mental health status after surviving COVID-19 in dialysis patients. In the present study, mental health had not yet recovered to the pre-COVID-19 level at 3 months after a COVID-19 diagnosis in only 6% of HD patients. In contrast with functional recovery, mental health recovery to pre-COVID-19 status was not significantly worse in HD patients who had been admitted to the ICU compared with the other two subgroups in our analysis. The most frequently reported limiting factors for mental health recovery were memory loss (35%), depression (31%) and anxiety (18%).

Survival at 3 months was almost identical to the survival at 28 days after presentation with COVID-19. Only in patients who at any time had been admitted to the ICU, a moderate decrease in survival probability from 47% to 40% observed between 28 days and 3 months after a COVID-19 diagnosis.

Table 2. Functional status at 3 months after a COVID-19 diagnosis in HD patients

Characteristics	Total ($N = 854$)	Not hospitalized ($n = 363$)	Hospitalized, no ICU ($n = 448$)	Hospitalized, ICU ($n = 43$)	P-value
Functional status					
Reached pre-COVID-19 status, n(%)					0.005
Yes	743 (87)	328 (90)	383 (85)	32 (74)	
No	111 (13)	35 (9.6)	65 (15)	11 (26)	
Limiting factor[a], n(%)					
Thromboembolic events[b]	1 (0.9)	0	1 (1.5)	0	0.7
Impaired lung function	10 (9.0)	4 (11)	4 (6.2)	2 (18)	0.36
Reduced mobility	45 (41)	14 (40)	26 (40)	5 (45)	0.94
Reduced muscle strength	53 (48)	16 (46)	29 (45)	8 (73)	0.22
Tiredness	41 (37)	10 (29)	28 (43)	3 (27)	0.28
Disturbed mental status	8 (7.2)	2 (5.7)	5 (7.7)	1 (9.1)	0.91
Declined cognitive function	12 (11)	4 (11)	8 (12)	0	0.31
Other[c]	82 (74)	25 (71)	47 (72)	10 (91)	0.40
Estimated time needed to reach pre-COVID-19 status, n(%)[a]					0.52
0–3 months	18 (16)	6 (17)	12 (18)	0	
3–6 months	27 (24)	8 (23)	15 (23)	4 (36)	
6–12 months	20 (18)	6 (17)	10 (15)	4 (36)	
>1 year	11 (10)	4 (11)	7 (11)	0	
Never	31 (28)	9 (26)	20 (31)	2 (18)	
Missing	4 3.6)	2 (5.7)	1 (1.5)	1 (9.1)	

[a] Figures do not add up to 100% since more than one answer was possible.
[b] Including stroke and pulmonary embolism.
[c] Including anxiety, depression and post-traumatic stress disorder.

Table 3. Mental health status in HD patients at 3 months after COVID-19 diagnosis

Characteristics	Total ($N = 854$)	Not hospitalized ($n = 363$)	Hospitalized, no ICU ($n = 448$)	Hospitalized, ICU ($n = 43$)	P-value
Mental health status					
Reached pre-COVID-19 status, n(%)					0.08
Yes	803 (94)	343 (94)	423 (94)	37 (86)	
No	51 (6.0)	20 (5.5)	25 (5.6)	6 (14)	
Limiting factor[a], n(%)					
Depression	16 (31)	9 (45)	6 (24)	1 (17)	0.23
Anxiety	9 (18)	5 (25)	3 (12)	1 (17)	0.52
Bereavement/grief	2 (3.9)	0	1 (4)	1 (17)	0.18
Memory loss	18 (35)	7 (35)	10 (40)	1 (17)	0.56
Delirium	2 (3.9)	0	2 (8)	0	0.34
Sleep disturbances	5 (9.8)	2 (10)	1 (4)	2 (33)	0.10
Other[b]	9 (18)	2 (10)	5 (20)	2 (33)	0.38
Estimated time needed to reach pre-COVID-19 status, n(%)[a]					0.35
0–3 months	6 (12)	2 (10)	4 (16)	0	
3–6 months	12 (24)	7 (35)	3 (12)	2 (33)	
6–12 months	10 (20)	5 (25)	4 (16)	1 (17)	
>1 year	5 (9.8)	0	4 (16)	1 (17)	
Never	14 (27)	4 (20)	9 (36)	1 (17)	
Missing	4 (7.8)	2 (10)	1 (4)	1 (17)	

[a] Figures do not add up to 100% since more than one answer was possible.
[b] Including, for example, itchy skin, diabetes mellitus type 1 complications and pain.

Survival in patients admitted to the ICU (40%) was much lower than in those who were not admitted (90%) and in those who were admitted to the hospital but not to the ICU (73%). The lower survival in dialysis patients who were admitted to the ICU is remarkable, especially considering the fact that these patients were younger and had a lower frailty score. In our opinion, this indicates that physicians in times of limited resources are in general more inclined to admit younger patients to an ICU, while they tend to be more hesitant to admit older and more frail patients, as it is assumed they have a lower chance of survival. Together with the relatively low proportion of patients who were admitted to the ICU, this suggests that strict triage has been performed. After ICU admission, 26% of the surviving HD patients had impaired functional outcome at 3 months follow-up, whereas there was no association between ICU admission and mental health recovery at 3 months. This observation suggests that it is important to consider physical revalidation after discharge, especially after ICU discharge.

The strength of our study is that we collected data on functional and mental health outcomes at 3 months after diagnosis in a large cohort of dialysis patients. The ERA-CODA database of patients with kidney replacement treatment

Table 4. Crude and adjusted ORs with 95% CIs for the likelihood that functional and mental health status recover 3 months after a COVID-19 diagnosis (yes versus no), among HD patients who survived 3 months after a COVID-19 diagnosis

Recovery of pre-COVID-19 functional status ($n = 854$)			Recovery of pre-COVID-19 mental health status ($n = 854$)		
Variables	Crude OR (95% CI)	Adjusted OR (95% CI)	Variables	Crude OR (95% CI)	Adjusted OR (95% CI)
Age (per year)	**0.97 (0.96–0.99)**	**0.98 (0.97–1.0)**	Age (per year)	**0.97 (0.95–0.99)**	0.99 (0.96–1.01)
Sex (male versus female)	0.99 (0.66–1.49)	0.94 (0.63–1.40)	Sex (male versus female)	1.17 (0.66–2.06)	1.02 (0.57–1.80)
Frailty score (per unit)	**0.77 (0.68–0.86)**	**0.79 (0.70–0.90)**	Frailty score (per unit)	**0.71 (0.61–0.83)**	**0.75 (0.63–0.90)**
Heart failure (yes versus no)	**0.60 (0.39–0.95)**	0.76 (0.49–1.19)	Heart failure (yes versus no)	**0.46 (0.25–0.83)**	0.75 (0.40–1.41)
			Coronary artery disease (yes versus no)	**0.49 (0.28–0.87)**	0.77 (0.43–1.37)
Respiration rate (per minute)	**0.93 (0.89–0.97)**	0.97 (0.92–1.02)	Respiration rate (per minute)	**0.93 (0.88–0.98)**	0.96 (0.90–1.02)
Shortness of breath (yes versus no)	**0.50 (0.33–0.74)**	0.75 (0.48–1.18)	Shortness of breath (yes versus no)	**0.49 (0.27–0.87)**	0.71 (0.38–1.35)
Hospitalization					
No hospitalization	1.0 (ref)	1.0 (ref)	No hospitalization	1.0 (ref)	1.0 (ref)
Hospitalization, no ICU	**0.63 (0.41–0.97)**	0.81 (0.51–1.28)	Hospitalization, no ICU	0.99 (0.54–1.81)	1.31 (0.68–2.51)
Hospitalization, ICU admitted	**0.31 (0.14–0.67)**	**0.43 (0.18–0.99)**	Hospitalization, ICU admitted	**0.36 (0.14–0.95)**	0.52 (0.17–1.57)

Statistically significant results are in bold.

*All variables analyzed crude were included in the multivariable models.

admitted for COVID-19 contains specifically collected granular data at the individual patient level, which enables detailed analysis of long-term effects of COVID-19. Data on outcome were complete for 84% of the patients with a known vital status at 3 months. Our analysis was not adversely influenced by selection bias on long-term outcome, because no significant or clinically relevant differences could be observed between patients with missing data on outcome and patients with complete data on outcome. We therefore consider our results representative for measuring functional and mental health outcomes in relation to the course of COVID-19 in HD patients.

This study also has limitations. First, not all dialysis patients with COVID-19 in the participating hospitals were recorded in ERACODA. Second, due to the design of the study, the assessment of functional and mental health status was performed by physicians, because we could not contact patients. This may have led to misclassification. However, the assessment by physicians was performed using a structured questionnaire, and nephrologists meet their HD patients on a regular basis in the dialysis facilities as part of a multidisciplinary team including social workers. Because they know their patients well, in general they are able to detect important differences in performance. Indeed, we found that nonrecovery of both functional and mental status at 3 months after a COVID-19 diagnosis was associated with clinical characteristics and disease severity parameters at admission, as well as with a greater likelihood of still being hospitalized and living in a nursing home. This reflects that the clinical judgement of treating nephrologists on these outcomes is valid.

In summary, survival in dialysis patients who survive after the initial COVID-19 episode is relatively preserved. The surviving patients recovered to the pre-existent level of functional and mental health within 3 months and most of them were living at home. Only patients who were admitted to the ICU have a substantial risk of mortality between 28 days and 3 months after diagnosis and of functional impairment. These are important clinical observations in which dialysis patients can find consolation in a rather uncertain time.

SUPPLEMENTARY DATA

Supplementary data are available at *ndt* online.

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The ERACODA collaboration is an initiative to study prognosis and risk factors for mortality due to COVID-19 in patients with a kidney transplant or on dialysis that is endorsed by the European Renal Association. The organizational structure contains a Working Group assisted by a Management Team and Advisory Board.

ERACODA Working Group: C.F.M. Franssen, R.T. Gansevoort (coordinator), M.H. Hemmelder, L.B. Hilbrands and K.J. Jager.

ERACODA Management Team: R. Duivenvoorden, M. Noordzij and P. Vart.

ERACODA Advisory Board: D. Abramowicz, C. Basile, A. Covic, M. Crespo, Z.A. Massy, S. Mitra, E. Petridou, JE. Sanchez and C. White.

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DATA AVAILABILITY STATEMENT

Collaborators who entered data in ERACODA remain the owners of these data. The database can therefore not be disclosed to any third party without prior written consent from all data providers, but the database will be made available to the editorial offices of medical journals when requested. Research proposals can be submitted to the Working Group via COVID.19.KRT@umcg.nl. If deemed of interest and methodologically sound by the Working Group and Advisory Board, the analyses needed for the proposal will be carried out by the Management Team.

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CONFLICT OF INTEREST STATEMENT

The results presented in this article have not been published previously in whole or part, except in abstract format.

APPENDIX

ERACODA Collaborators

Jeroen B. van der Net (Albert Schweitzer Hospital, Dordrecht, The Netherlands); Marie Essig (Ambroise Pare Hospital, APHP Paris-Saclay University, Boulogne Billancourt, France); Peggy W.G. du Buf-Vereijken, Betty van Ginneken and Nanda Maas (Amphia Hospital, Breda, The Netherlands); Brigit C. van Jaarsveld, Frederike J. Bemelman, Farah Klingenberg-Salahova, Frederiek Heenan-Vos, Marc G. Vervloet and Azam Nurmohamed (Amsterdam UMC, Amsterdam, The Netherlands); Daniel Abramowicz and Sabine Verhofstede (Antwerp University Hospital, Antwerp, Belgium); Omar Maoujoud (Avicennes Military Hospital, Faculty of Medicine, Cadi Ayyad University, Marrakech Morocco); Thomas Malfait (AZ Delta, Roeselare, Belgium); Jana Fialova (B. Braun Avitum, Litomerice, Czech Republic); Edoardo Melilli, Alexandre Favà, Josep M. Cruzado and Nuria Montero Perez (Bellvitge University Hospital, Hospitalet de Llobregat, Barcelona, Spain); Joy Lips (Bernhoven Hospital, Uden, The Netherlands); Harmen Krepel (Bravis Hospital, Roosendaal/Bergen op Zoom, The Netherlands); Harun Adilovic (Cantonal Hospital Zenica, Bosnia and Herzegovina); Maaike Hengst and Constantijn J.A.M. Konings (Catharina Hospital, Eindhoven, The Netherlands); Philippe Braconnier and Daniel Weis (Centre Hospitalier du Nord, Luxembourg); Ryszard Gellert (Centre of Postgraduate Medical Education, Warsaw, Poland); Daniela G. Alferes (Centro Hospitalar Vila Nova de Gaia/Espinho, Vila Nova de Gaia, Portugal); Daniela Radulescu ('Carol Davila' University of Medicine and Pharmacy, Bucharest, Romania/Emergency Clinical Hospital 'Sf. Ioan'); Elena V. Zakharova (City Hospital n.a. S.P. Botkin, Moscow, Russia); Patrice Max Ambuehl, Rebecca Guidotti and Andrea Walker (City Hospital Zuürich, Zürich, Switzerland); Fanny Lepeytre, Clémentine Rabaté and Guy Rostoker (Claude Galien Hospital Ramsay santé, Quincy-sous-Sénart, France); Sofia Marques (Clínica de Hemodiálise de Felgueiras, Felgueiras, Portugal); Tijana Azasevac and Gordana Strazmester Majstorovic (Clinical Centre of Vojvodina, Novi Sad, Serbia); Dajana Katicic (Croatian Society of Nephrology, Dialysis and Transplantation, Zagreb, Croatia); Marc ten Dam (CWZ Nijmegen, Nijmegen, The Netherlands); Thilo Krüger (DaVita Geilenkirchen, Geilenkirchen, Germany); Szymon Brzosko (DaVita, Wrocław, Poland); Vassilios Liakopoulos (1st Department of Internal Medicine, Medical School, Aristotle University of Thessaloniki, Thessaloniki, Greece); Adriaan L. Zanen (Deventer Ziekenhuis, Deventer, The Netherlands); Susan J.J. Logtenberg (Dianet Dialysis Center, Utrecht, The Netherlands); Lutz Fricke (Dialysis Center Bochum, Bochum, Germany); Olexandr Kuryata (Dnipro State Medical University, Dnipro, Ukraine); Jeroen J.P. Slebe (Elyse Klinieken voor Nierzorg, Kerkrade, The Netherlands); Samar Abd ElHafeez (Epidemiology Department, High Institute of Public Health, Alexandria University, Alexandria, Egypt); Delphine Kemlin (Erasme Hospital, Brussels, Belgium); Jacqueline van de Wetering, Marlies E.J. Reinders, Dennis A. Hesselink and J. Kal- van Gestel (Erasmus MC Transplant Institute, Department of Internal Medicine, University Medical Center Rotterdam, Rotterdam, The Netherlands); Jaromir Eiselt and Lukas Kielberger (Faculty of Medicine in Pilsen, Charles University, Pilsen, Czech Republic); Hala S. El-Wakil (Faculty of Medicine, Alexandria University, Alexandria, Egypt); Martine A.M. Verhoeven (Franciscus Gasthuis and Vlietland, Schiedam, The Netherlands); Ian Logan (Freeman Hospital, Newcastle upon Tyne, UK); Cristina Canal and Carme Facundo (Fundació Puigvert, Barcelona, Spain); Ana M. Ramos (Fundación Jiménez Díaz, Madrid, Spain); Alicja Debska-Slizien (Gdansk Medical University, Gdansk, Poland); Nicoline M.H. Veldhuizen (Gelre Hospital, Apeldoorn, The Netherlands); Eirini Tigka (General Hospital of Athens 'G. Gennimatas', Athens, Greece); Maria Anna Polyzou Konsta (General Hospital of Serres, Serres, Greece); Stylianos Panagoutsos (General University Hospital of Alexandroupolis, Alexandroupolis, Greece); Adele Postorino and Francesco Cambareri (Grande Ospedale Metropolitano and CNR, Reggio Calabria, Italy); Irina Matceac, Ionut Nistor and Adrian Covic (Grigore T Popa University of Medicine and Pharmacy, Iasi, Romania/Dr Ci Parhon Hospital, Iasi, Romania); J.H.M Groeneveld and Jolanda Jousma (Haaglanden Medisch Centrum, The Hague, The Netherlands); Fritz Diekmann, Federico Oppenheimer and Miquel Blasco (Hospital Clínic de Barcelona, Barcelona, Spain); Tiago Assis Pereira (Hospital Curry Cabral—Central Lisbon University Hospital Center, Lisbon, Portugal); Augusto Cesar Soares dos Santos Junior (Hospital das Clinicas UFMG, Contagem, Brazil); Carlos Arias-Cabrales, Marta Crespo, Laura Llinàs-Mallol, Anna Buxeda, Carla Burballa Tàrrega, Dolores Redondo-Pachon, Maria Dolores Arenas Jimenez and Alberto Mendoza-Valderrey (Hospital del Mar, Barcelona, Spain); Ana Cristina Martins, Catarina Mateus, Goncalo Alvila and Ivo Laranjinha (Hospital de Santa Cruz, Centro Hospitalar de Lisboa Ocidental, Lisbon, Portugal); Julia M. Hofstra, and Machiel A. Siezenga (Hospital Gelderse Vallei, Ede, The Netherlands); Antonio Franco (Hospital General of Alicante, Alicante, Spain); Sandra Castellano and Maria Luisa Rodríguez-Ferrero (Hospital General Universitario Gregorio Marañón, Madrid, Spain); Sagrario Balda Manzanos (Hospital Obispo Polanco, Salud Aragón, Spain); R. Haridian Sosa Barrios, (Hospital Universitario Ramón y Cajal, Madrid, Spain); Wim Lemahieu (Imelda Hospital, Bonheiden, Belgium); Karlijn Bartelet (Isala, Zwolle, The Netherlands); Ahmet Burak Dirim, Erol Demir, Mehmet Sukru Sever, Aydin Turkmen and Seda Şafak (Istanbul Faculty of Medicine, Istanbul University, Istanbul, Turkey); Daan A.M.J. Hollander and Angele Kerckhoffs (Jeroen Bosch Ziekenhuis, Den Bosch, The Netherlands); Stefan Büttner (Klinikum Aschaffenburg-Alzenau, Aschaffenburg, Germany); Aiko P.J. de Vries, Soufian Meziyerh, Danny van der Helm, Marko Mallat and Hanneke Bouwsma (Leiden University Medical Center, Leiden, The Netherlands); Kristina Petruliene (Lithuanian University of Health Sciences, Kaunas, Lithuania); Iris Verberk (Maasstad Ziekenhuis, Rotterdam, The Netherlands); Frank M. van der Sande and Maarten H.L. Christiaans (Maastricht University Medical Center, Maastricht, The Netherlands); N. MohanKumar (Manipal Hospital, Manipal, India); Marina Di Luca (Marche Nord Hospital, Pesaro, Italy); Serhan Z. Tuğlular (Marmara University School of Medicine, Istanbul, Turkey); Andrea Kramer (Martini Ziekenhuis, Groningen, The Netherlands); Charles Beerenhout (Maxima Medisch Centrum, Veldhoven, The Netherlands); Peter T. Luik (Meander Medisch Centrum, Amersfoort, The Netherlands); Julia Kerschbaum (Austrian Dialysis and Transplant Registry, Rohr, Austria); Martin Tiefenthaler (Medical University Innsbruck, Innsbruck, Austria); Bruno Watschinger (Medical University of Vienna, Vienna, Austria); Aaltje Y. Adema (Medisch Centrum Leeuwarden, Leeuwarden, The Netherlands); Vadim A. Stepanov and Alexey B. Zulkarnaev (Moscow Regional Research and Clinical Institute, Moscow, Russia); Kultigin Turkmen (Necmettin Erbakan University Meram School of Medicine, Konya, Turkey); Ilaria Gandolfini and Umberto Maggiore (Nephrology Unit, Department of Medicine and Surgery, University of Parma, Parma, Italy); Anselm Fliedner (Nierenzentrum Reutlingen-Tübingen, Reutlingen, Germany); Anders Åsberg and Geir Mjoen (Norwegian Renal Registry, Oslo University Hospital Rikshospitalet, Olso, Norway); Hitoshi Miyasato (Okinawa Chubu Hospital, Nakagami, Japan); Carola W.H. de Fijter (OLVG, Amsterdam, The Netherlands); Nicola Mongera (Ospedale S. Maurizio Bolzano, Bolzano, Italy); Stefano Pini (Padua University Hospital, Padua, Italy); Consuelo de Biase, Anne Els van de Logt and Rutger Maas (Radboud University Medical Center, Nijmegen, The Netherlands); Olga Lebedeva (Regional Clinical Hospital, Yaroslavl, Russia); Veronica Lopez (Regional Hospital of Malaga, Malaga, Spain); Louis J.M. Reichert and Jacobien Verhave (Rijnstate Hospital, Arnhem, The Netherlands); Denis Titov (RUDN University, Moscow, Russia); Ekaterina V. Parshina (Saint Petersburg State University Hospital, Saint-Petersburg, Russia); Luca Zanoli and Carmelita Marcantoni (San Marco Hospital, University of Catania, Catania, Italy); Gijs van Kempen (Saxenburgh Medisch Centrum, Hardenberg, The Netherlands); Liesbeth E.A. van Gils-Verrij (Sint Antonius Ziekenhuis, Nieuwegein, The Netherlands); John C. Harty (Southern Health and Social Care Trust, Newry, Northern Ireland); Marleen Meurs (Spaarne Gasthuis, Haarlem, The Netherlands); Marek Myslak (SPWSZ Hospital, Szczecinie, Poland); Paolo Lentini (St. Bassiano Hospital, Bassano del Grappo, Italy); Edwin den Deurwaarder (Streekziekenhuis Koningin Beatrix, Winterswijk, The Netherlands); Maria Stendahl (Swedish Renal Registry, Jönköping, Sweden); Hormat Rahimzadeh (Tehran University of Medical Sciences, Tehran, Iran); Marcel Schouten (Tergooi, Hilversum, The Netherlands); Ivan Rychlik (Third Faculty of Medicine, Charles University and Faculty Hospital Kralovske Vinohrady, Prague, Czech Republic); Carlos J. Cabezas-Reina and Ana Maria Roca (Toledo University Hospital, Toledo, Spain); Ferdau Nauta (Treant/Scheper Ziekenhuis, Emmen, The Netherlands); İdris Sahin (Turgut Ozal Medical Center, Malayta, Turkey); Eric Goffin, Nada Kanaan, Laura Labriola and Arnaud Devresse (Université Catholique de Louvain, Cliniques universitaires St Luc, Brussels, Belgium); Anabel Diaz-Mareque (University Clinical Hospital of Santiago de Compostela, Santiago de Compostela, Spain); Armando Coca (University Clinical Hospital of Valladolid, Valladolid, Spain); Gabriel de Arriba (Universitary Hospital of Guadalajara, Guadalajara, Spain); Björn K.I. Meijers, Maarten Naesens, Dirk Kuypers and Bruno Desschans (University Hospital Leuven, Leuven, Belgium); Annelies Tonnerlier and Karl M. Wissing (University Hospital Brussels, Brussels, Belgium); Ivana Dedinska (University Hospital Martin and Jessenius Faculty of Medicine Comenius University, Martin, Slovakia); Giuseppina Pessolano (University Hospital Medical Center Verona, Verona, Italy); Shafi Malik (University Hospitals of Coventry and Warwickshire NHS Trust, Coventry, UK); Evangelia Dounousi (University Hospital of Ioannina, Ioannina, Greece); Evangelos Papachristou (University Hospital of Patras, Patras, Greece); Stefan P. Berger, Esther Meijer and Jan Stephan F. Sanders (University Medical Center Groningen, Groningen, The Netherlands); Akin Özyilmaz (Dialysis Center Groningen, Groningen, The Netherlands); Jadranka Buturović Ponikvar, Andreja Marn Pernat, Damjan Kovac and Miha Arnol (University Medical Center Ljubljana, Ljubljana, Slovenia); Femke M. Molenaar, Arjan D. van Zuilen, Sabine C.A. Meijvis and Helma Dolmans (University Medical Center Utrecht, Utrecht, The Netherlands); Ekamol Tantisattamo (University of California Irvine School of Medicine, Orange, CA, USA); Pasquale Esposito (University of Genoa, Genoa, Italy); Jean-Marie Krzesinski and Jean Damacène Barahira (University of Liége, Liége, Belgium); Maurizio Gallieni (University of Milan, Milan, Italy); Paloma Leticia Martin-Moreno (University of Navarra Clinic, Pamplona, Spain); Gabriele Guglielmetti (University of Piemonte Orientale, Novara, Italy); Gabriella Guzzo (Valais Hospital, Sion and Lausanne University Hospital, Lausanne, Switzerland); Nestor Toapanta and Maria Jose Soler (Vall d'Hebron University Hospital, Barcelona, Spain); Antinus J. Luik, Willi H.M. van Kuijk, Lonneke W.H. Stikkelbroeck and Marc M.H. Hermans (VieCuri Medical Centre, Venlo, The Netherlands); Laurynas Rimsevicius (Vilnius University, Vilnius, Lithuania); Marco Righetti (Vimercate Hospital, Vimercate, Italy); Mahmud Islam (Zonguldak Ataturk State Hospital, Zonguldak, Turkey); Nicole Heitink-ter Braak (Zuyderland Medical Center, Geleen and Heerlen, The Netherlands).

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