Clinical Kidney Journal, 2023, vol. 16, no. 1, 138–150

https://doi.org/10.1093/ckj/sfac204
Advance Access Publication Date: 12 September 2022
Original Article

ORIGINAL ARTICLE

Pregnancy in women on chronic dialysis in the last decade (2010–2020): a systematic review

Hayet Baouche [1], Jean-Philippe Jais[2], Samy Meriem[3], Mimi Kareche[4], Olivier Moranne [5,6], Cécile Vigneau[7] and Cécile Couchoud [8]

[1]Department of Biostatistics, APHP–Necker–Enfants Malades Hospital, REIN Registry, Paris, France, [2]Department of Biostatistics, APHP–Necker–Enfants Malades Hospital, REIN Registry, University of Paris Cité, Paris, France, [3]Department of Biostatistics, APHP–Necker–Enfants Malades Hospital, Paris, France, [4]NephroCare Etampes, France, [5]Service Nephrologie–Dialyse–Apherese, Hopital Universitaire de Nimes, CHU Caremeau Nîmes, France, [6]IDESP, UMR, Université de Montpellier, France, [7]University of Rennes, CHU Rennes, INSERM, EHESP, IRSET (Institut de recherche en santé, environnement et travail) –UMR S1085, Rennes, France and [8]REIN Registry, Agence de la biomédecine, Saint Denis La Plaine, France

Correspondence to: Hayet Baouche; E-mail: hayet.baouche@aphp.fr

ABSTRACT

Background. Pregnant women with end-stage renal disease on chronic dialysis are at a high risk of maternal and foetal complications. Over the years, the prognosis of their pregnancies has improved with advances in dialysis treatments and maternal and neonatal care. We conducted this systematic review to examine the recent data on maternal and foetal outcomes in pregnant women with end-stage renal failure on chronic dialysis over the last decade.

Methods. We made a systematic review of studies on pregnant women on chronic dialysis published between 1 January 2010 and 31 December 2020. We searched the following electronic databases: Medline via PubMed, Embase and the Cochrane Library, with search strategies for each database. We checked the titles and abstracts identified by the search equation, and two independent reviewers assessed the articles retrieved. For each study, the two reviewers separately recorded the data from each selected article on a standardized data extraction form. For each article, we recorded relevant general information on the study, patient demographic characteristics, dialysis schedule, pregnancy complications and outcomes, maternal complications, and foetal and neonatal outcomes.

Results. The literature search yielded 1668 potentially relevant abstracts. After reviewing the titles, abstracts and full text, we identified 14 studies according to the inclusion criteria. All studies were observational, nine of them were retrospective and eight were from a single-centre experience. The total number of women included in these studies was 2364 (range 8–2008) and the total number of pregnancies was 2754 (range 8–2352). The patients' ages ranged from 15 to 45 years. Obesity was observed in 808 (34.2%) women and ranged from 1 to 778. Haemodialysis was the predominant modality with 2551 (92.6%) pregnancies, and 203 (7.4%) on peritoneal dialysis. Overall, 68 out of 402 (16.9%) spontaneous miscarriages, 21 out of 402 (5.2%) therapeutic abortions and 26 (8.3%) stillbirths among 313 (stillbirths and live births) were recorded. The mean or median gestational age at delivery ranged from 25.2 to 36 weeks. The main maternal complications were preeclampsia 11.9%, hypertension 7.7% and anaemia 3.9%. Live births represented 287 (71.4%) out of 402 pregnancies, birth weight ranged from 590 to 3500 g and preterm birth was the main, most common complication in all studies, ranging from 50% to 100%. Intrauterine growth restriction was present in 5.9% and small-for-gestational-age

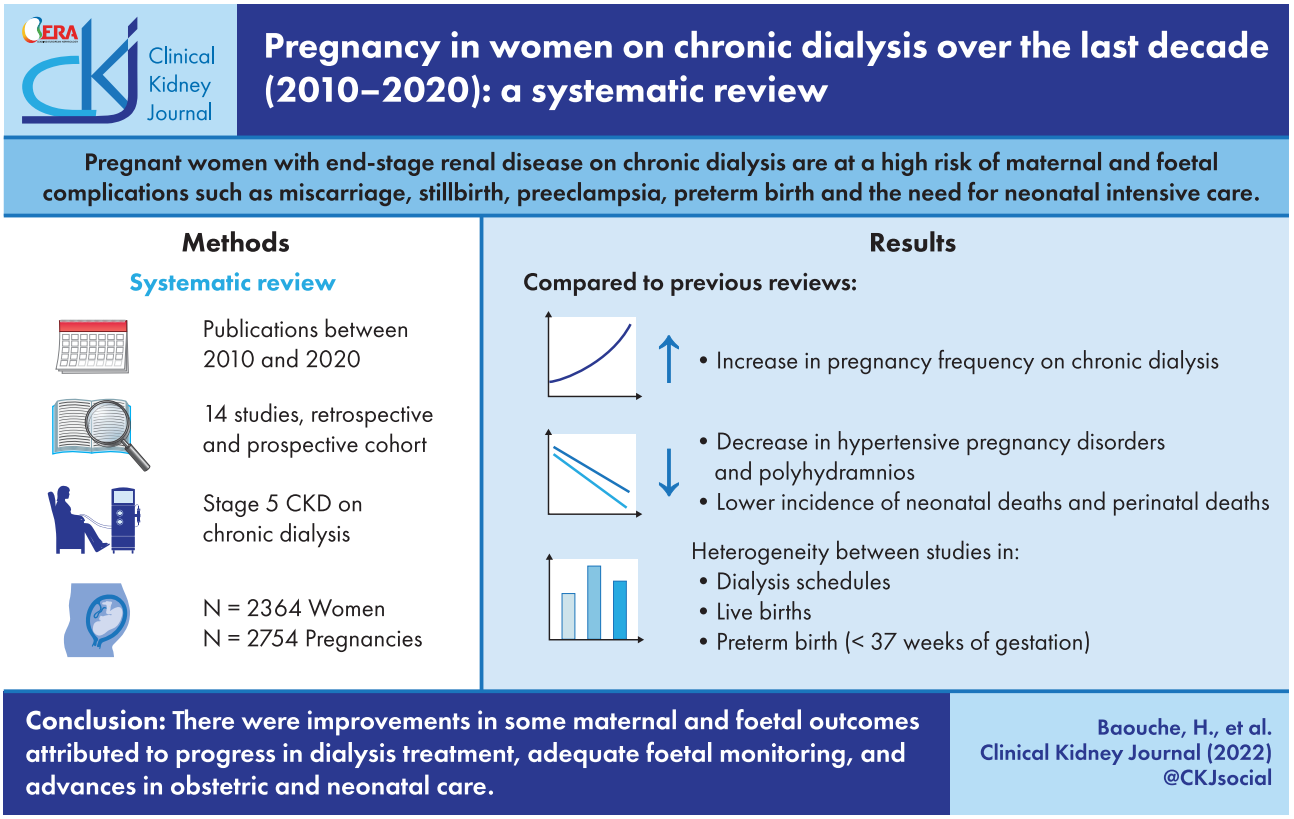
Received: 25.5.2022; Editorial decision: 2.9.2022

was reported in 18.9% of neonates. There were 22 (7.6%) neonatal deaths among 287 live births and 48 (15.3%) perinatal deaths among 313 total births (stillbirths and live births).
Conclusions. Presumably, considering the increase in the number of publications and the total number of pregnancies reported therein, the frequency of pregnancy in patients with end-stage chronic kidney disease treated by chronic dialysis has increased. However, the practice of treating pregnant women on dialysis differs significantly among countries. These findings highlight the need to standardize the definition of outcomes and healthcare for pregnant women on dialysis.

LAY SUMMARY

Pregnant women with end-stage renal disease on chronic dialysis are at a high risk of maternal and foetal complications such as miscarriage, stillbirth, preeclampsia, anaemia, polyhydramnios, preterm birth and the need for neonatal intensive care. Over the years, the prognosis of their pregnancies has improved with advances in dialysis treatments and maternal and neonatal care. We made a systematic review of studies on pregnant women on chronic dialysis published between 1 January 2010, and 31 December 2020, to examine the recent data on maternal and foetal outcomes. We identified 14 studies. The total number of women in studies was 2364, and the total number of pregnancies was 2754. We show an increase in pregnancy frequency on chronic dialysis and improvements in some maternal and fetal outcomes. This is of clinical importance for these women, helping their physicians in clinical practices and increasing their confidence in supporting a parental project.

GRAPHICAL ABSTRACT



Keywords: chronic kidney failure, pregnancy, pregnancy complications, pregnancy outcome, renal dialysis

INTRODUCTION

Pregnant women on chronic dialysis for end-stage renal disease are at a high risk of maternal and foetal complications [1, 2] including miscarriage, stillbirth, medical pregnancy interruption, arterial hypertension, preeclampsia, anaemia, polyhydramnios, intrauterine growth restriction, small-for-gestational age infants, preterm birth and the need for neonatal intensive care [3–5].

Since the world's first case of pregnancy and successful delivery in a chronic haemodialysis patient in the 1970s, there

has been an increase in the number of pregnancies in recent years, probably partly due to the improvement in prognosis. Pregnancy is thus more acceptable, leading to less frequent recourse to therapeutic interruption. However, beyond all the improvements in dialysis conditions, allowing more time on dialysis and maintaining low levels of pre-dialysis urea to avoid maternal hypertension, other improvements such as correction of anaemia, adequate foetal monitoring, and advances in obstetric and neonatal care are also responsible for this significant increase [6–8].

We conducted a systematic review to examine recent data on maternal and foetal outcomes in pregnant women on chronic dialysis with end-stage renal disease published over the last decade (2010–2020).

MATERIALS AND METHODS

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [9] and the MOOSE consensus statement on the conduct of Meta-analysis Of Observational Studies in Epidemiology [10].

Inclusion criteria

We included all studies reporting maternal or foetal outcomes in pregnant women with end-stage renal disease who had conceived during chronic dialysis (haemodialysis or peritoneal dialysis). The analysis was limited to observational data if a control group was available. Due to the heterogeneity of management, context, length of observation and reporting biases, we retained only those articles that reported at least five cases.

Exclusion criteria

Studies on pregnant women with a diagnosis of acute kidney failure, studies on kidney transplanted pregnant women, studies with a completion date before 2000 and those with missing data on the study period were excluded. We also excluded studies begun before the new millennium as, at that time, the dialysis schedule was different, erythropoietin was not prescribed for all patients, and obstetric monitoring and care of newborns were different from nowadays. Abstracts, letters, duplicates, preliminary publications, reviews, comments, notes and editorials were also excluded.

Search strategy

We searched the electronic databases: Medline via PubMed, Embase and Cochrane Library with search strategies for each database, using a combination of the following text words and index terms: [pregnancy, pregnant, pregnancy complications, chronic kidney disease, chronic dialysis, haemodialysis and peritoneal dialysis]. The search strategies are detailed in Appendix 1. We also reviewed the reference lists of included studies and included all studies published between 1 January 2010 and 31 December 2020. There were no language restrictions.

From the references identified by the search equation, we then selected studies based on title and abstract. We selected all studies reporting maternal and foetal outcomes in pregnant women on chronic dialysis. Full-text publications of remaining abstracts were retrieved and carefully examined for any study that potentially met the inclusion criteria. For completeness of data, we contacted the authors for additional unpublished information.

Data extraction

Using a standardized data extraction form, two independent reviewers, tested beforehand on a sample of eight studies, extracted the data. For each study, the following data were retrieved: general study information (the first author's name, country, period of study, objective, study design and control group whenever available); patient demographic characteristics [number of women, number of pregnancies, maternal age, parity, cause of end-stage renal dialysis, mode of dialysis (haemodialysis, peritoneal dialysis), dialysis schedule and comorbidities]; pregnancy complications and outcomes (spontaneous miscarriages, therapeutic abortions, antepartum haemorrhage, polyhydramnios, premature rupture of membranes, stillbirths, preterm delivery, indications for delivery, mode of delivery and gestational age at delivery); maternal complications (hypertension, preeclampsia, gestational diabetes, peritonitis, maternal deaths and other maternal complications); and neonatal outcomes and complications (live births, birth weights, small-for-gestational-age $<$10th percentile, Apgar scores, need of neonatal intensive care unit and neonatal deaths).

Two reviewers (H.B., S.M.) independently screened all potentially eligible articles and a third reviewer (M.K.) adjudicated any discrepancy between these two investigators. Each reviewer independently assessed the quality of each study according to the Newcastle-Ottawa Scale (NOS) quality assessment scale for observational studies, in which each item is awarded with a star per section. The number of stars indicates the number of items awarded, with results ranging from 0 to 9 stars [11].

Statistical analysis

For data synthesis, we described the studies narratively and tabulated their characteristics. Descriptive analysis was performed by estimating frequencies and percentages for qualitative variables when the data allowed pooling. However, for continuous variables, combining the heterogeneous evidence retrieved was difficult as the results from the various studies were in different forms. Some studies presented results with medians, first and third quartiles or with minimum and maximum values. Others reported mean and standard deviations, with no claim as to their data following or satisfying the assumptions of normality. We therefore performed a systematic review, not a meta-analysis. The only larger study included had a high number of unknown cases, which led us to use only valid data from small studies on pregnancy outcomes, maternal and neonatal complications. Agreement between the two reviewers was assessed using the Kappa (κ) statistic [12].

In our calculation, we used three different denominators 'total number of pregnancies' and 'total number of birth' (stillbirth + live birth) and 'number of live birth'.

A 'total number of pregnancies' of 402 was used as the denominator for calculating miscarriage, therapeutic abortion and live birth. However, for the percentage of stillbirth and perinatal death, we used 'total number of birth' 313. Whereas for the calculation of the percentage of neonatal death, we used the only number of live births, 287, following the World Health Organization International Classification of Diseases 10 (WHO ICD-10)

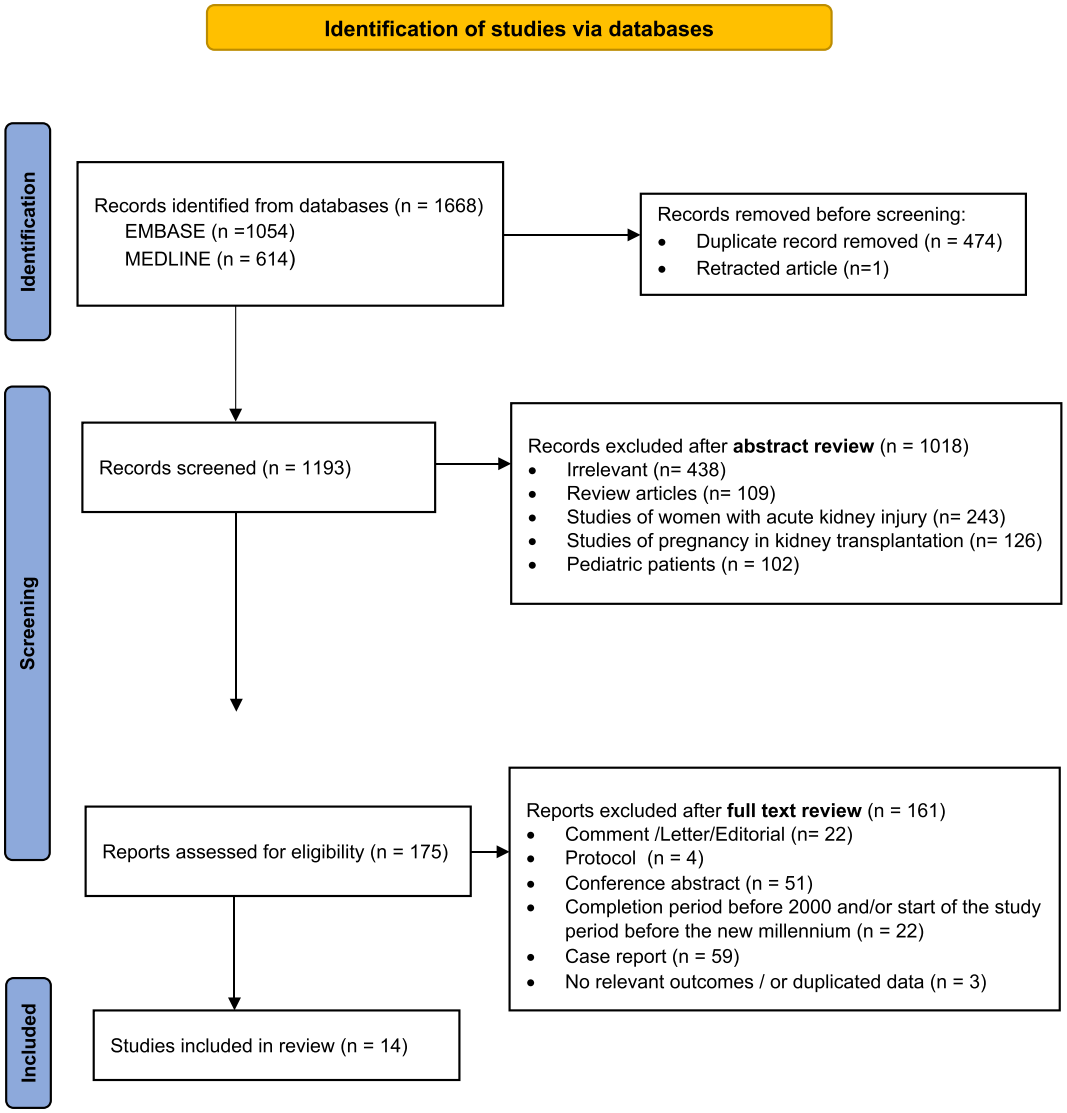


Figure 1: Flow diagram for literature search and study selection.

definitions and international statistical classification of diseases and related health problems. All analyses were performed using version 4.1.2 of R statistical software.

RESULTS

The literature search yielded 1668 potentially relevant abstracts. After reviewing titles, abstracts and full text, we retained 14 studies identified according to the inclusion criteria (Fig. 1). We found no studies in the Cochrane Library that met the inclusion criteria for the 2010–20 period. Overall, the quality of the evidence was good, with NOS scores of 6 to 8 (Supplementary data, Table S1). Inter-reviewer agreement for the study was excellent with (κ) of 89%.

General study characteristics

Table 1 summarizes the characteristics of the studies included. These studies were run between 2000 and 2017, and were from different geographical origins. There were 14 studies from 11 countries: 6 studies from South America, 3 from North America, 2 from Africa, 1 from Europe, 1 from Asia and 1 from Oceania. All studies were observational, with nine of them being retrospective, three being prospective, one a registry study, and one both retrospective and prospective. There were eight single-centre studies, six multicentre studies and seven without a control group.

Patient demographic characteristics and dialysis schedules

The total number of women in the studies was 2364 (range 8–2008), representing a total number of 2754 pregnancies (range 8–2352 because case reports below 5 were not included), with 5 twin pregnancies (Table 2). The mean or median age of patients ranged from 22.1 ± 4.9 to 38.3 ± 6 years. Obesity was observed in 808 (34.2%) women and ranged from 1 to 778 (Supplementary data, Table S2). The causes of end-stage renal disease were reported in 13 out of 14 studies (2177 women); data were available

Table 1: Characteristics of the included studies.

Author [Ref], publication year	Period of study	Country	Design	*N* W, *N* preg	Objectives of study	Dialysis HD	Dialysis PD	Control group
Ibarra-Hernandez [13], 2019	2013–17	Mexico	Pro, mono	15, 15	To report maternal-foetal outcomes in a prospective cohort of poor CKD pregnant women, and compare results with those of pregnant women without CKD	15	0	Pregnant women without CKD
Luders [14], 2018	2000–17	Brazil	Retro, mono	89, 93	To identify baseline risk factors for pregnancy outcomes and to evaluate the association between several dialysis parameters and the risk of adverse events	93	0	
Moscoso Solorzano [15], 2019	2014–16	Ecuador	Pro, mono	8, 8	To describe experiences of management of pregnancy in CKD in a single Medical Centre in a South America Country, Ecuador	8	0	Women with CKD non-dialysis dependent
Hirano [16], 2021	2012–16	Japan	Retro, multi	15, 19	To investigate the prevalence and outcomes of pregnancy in women undergoing dialysis and assessed risk factors associated with neonatal and maternal complications	19	0	
Hoffman [17], 2020	2012–16	USA	Pro and retro, multi	10, 10	To describe maternal and foetal outcomes in women requiring chronic dialysis during pregnancy and to examine pregnancy complications based on the underlying cause of renal disease in these patients	10	0	Women with dialysis indications other than diabetes and lupus
Megahed [18], 2020	2011–16	Egypt	Retro, multi	33, 57	To assess the frequency of pregnancy in women on HD in Egypt and to study the pregnancy outcome and factors affecting it	57	0	Females without HD-coincidental pregnancies
Fiedler [19], 2019	2001–16	Chile	Retro, mono	11, 13	To describe a 16-year experience of treating pregnant women on haemodialysis and to analyse maternal-foetal outcomes	13	0	
Hernández Rivera [20], 2019	2002–14	Mexico	Retro, mono	40, 40	To analyse the clinical outcomes in pregnant women with CKD who required dialysis in pregnancy	40	0	
Shah [21], 2019	2005–13	USA	Retro, multi	2008, 2352	To determine pregnancy rates in women with ESKD who were on dialysis at any time between 1 January 2005 and 31 December 2013	2160	192	Women who did not conceive
Hladunewich [22], 2014	2000–13	Canada	Pro, mono	17, 22	To compare pregnancy outcomes from 22 pregnancies on intensive dialysis in Toronto from 2000 to 2013 with 70 pregnancies in the American RPDP (1990–2011)	22	0	70 pregnancies in the American RPDP
Suarez [23], 2015	2003–12	Brazil	Retro, mono	14, 14	To evaluate perinatal outcomes and maternal complications in pregnant women under dialysis in a Brazilian high-risk reference centre	14	0	
Piccoli [24], 2014	2000–12	Italy	Retro, multi	23, 23	To assess the incidence of live births from mothers on chronic dialysis compared with the overall population and with kidney transplant patients	20	3	Overall population and kidney transplant patients
Jesudason [25], 2014	2001–11	Australia	Registry	73, 77	To describes a large series of pregnancies in women undergoing long-term dialysis treatment and reviews maternal and foetal outcomes	69	8	Women who had conceived after starting long-term dialysis
Hadj Sadek [26], 2011	2000–10	Morocco	Retro, mono	8, 11	To report the experience in management of pregnancies occurred in haemodialysis patients, and clarify the factors of good prognosis	11	0	

HD, haemodialysis; PD, peritoneal dialysis; COD, conception on dialysis; CBD, conception before dialysis; W, women; Preg, pregnancies; Retro, retrospective; Pro, prospective; Mono, monocentric, Multi, multicentric; CKD, chronic kidney disease; ESKD, end-stage kidney disease; RPDP, American Registry for Pregnancy in Dialysis Patients.

Table 2: Pregnancy, maternal, foetal complications and neonatal outcomes.

Author [Ref], publication year, country	N W, preg	Age (years)	Miscar	Abort	Still birth	Live birth	Full term	Neonatal deaths	Gestational age (mean/median)	Birth weight (g)	Mode of delivery	Preterm delivery	Maternal and pregnancy complications	Foetal and neonatal complications	Preterm birth categories
Ibarra-Hernandez [13], 2019, Mexico	15, 15	22.1 ± 4.9	2 (13.3%)	0	1 (6.7%)	12 (80%)	0	0	35 (32–36)	2225 (970–2485), LBW 8 (72.7%), VLBW 3 (27.3%)	CS 12 80%	12	PE 4 (26.7%), eclampsia 1 (6.7%)	IUGR 1 (8.3%), SGA 5 (41.5%), NICU 5 (41.5%)	Preterm delivery (<37 wk) 9 (75%), early preterm (<34 wk) 3 (25%), very early preterm (<28 wk) 0
Luders [14], 2018, Brazil	89, 93; 4 W >1 preg	30 ± 5.0	0	0	10	83 (89.2%) + 2 twins	NR	0	35 (25–39) (excluding 5 stillbirths)	1698 ± 719	CS 69 (74.2%)	74%	PE 13 (14%), hydramnios 49 (52.7%)	SGA 45 (48.4%), NICU 60 (70%)	Late preterm (34–37 wk) 33, early preterm (30–34 wk) NR, extreme preterm (<30 wk) 9
Moscoso Solorzano [15], 2019, Ecuador	8, 8	29 ± 4.9	2 (25%)	0	0	6 (75%)	0	2 (33%)	31 ± 2.8	1913 ± 508, 2500–1000: 2 (33%), <1000: 4 (67%)	NR	6	Severe HDP 4 (50%), HELLP 1 (12.5%), PE 1 (12.5%),	NICU 5 (83%)	NR
Hirano [16], 2021, Japan	15, 19; 2 W 3 preg	34.6 ± 5.7 (21–40)	4 (21.1%)	1 (5.3%)	0	14 (73.7%)	5 (36%)	0	33.7 ± 4.5	1853 ± 694, LBW 8, VLBW 1, ELBW 2	CS 10	9 (64.3%)	severe hypertension 5, PROM 1, preterm labour 5, cervical insufficiency 4	FGR 4, RDS 2 rickets 2, ASD 1, retinopathy 1, epilepsy 1, VSD 1, cerebral palsy 1, primary glaucoma1	Late preterm (32–37 wk) 4 (29%), mid preterm (28–32 wk) 2 (14%), extremely preterm (<28 wk) 3 (21%)
Hoffman [17], 2020, USA	10, 10	31.9 (20–37)	0	3	2	5	0	2	25.2 (23.4–35.1)	1322 ± 915	CS 5 (71.4%)	5	PE 2 (28.6%), PROM 1 (14%), preterm labour 2 (28.6%), oligoamnios 2 (28.6%), chorioamnionitis 2 (28.6%)	IUGR 3 (57%), NEC 1 (20%), sepsis 1 (20%), SGA 2 (44.4%), NICU 5 (100%)	Late preterm (34–36 wk) 2, very preterm (29–33 wk) 0, extremely preterm (<28 wk) 3
Megahed [18], 2020, Egypt	33, 57; 16 W >1 preg	38.3 ± 6 (24–50)	36 (63.1%)	0	2 (9.5%)	19 (33.3%)	0	3 14%	34 (24–36)	1950 (900–3500)	CS 15 (71.15%)	19 (100%)	NR	Mentally Retard 4.5% NICU	NR
Fiedler [19], 2019, Chile	11, 13	30 (23–32) IQR (20–38)	1	0	1	11	NR	2 (18%)	34 (29–34) IQR	1880 (1020–2675), LBW 6, VLBW 4, 1 NR	CS 12 (100%)	9 + 2 NR	HTN 7 (54%), PROM 1 (7.7%), AN 6 (46%), hydramnios 4 (31%), PE 1 (7.6%), cholestasis 3 (23%)	IUGR 3 (23%), NICU 5 (45.4%)	Preterm (<37 wk) 6, very preterm (<34 wk) 3, extreme preterm (<28 wk) 0, 2 NR
Hernández Rivera [20], 2019, Mexico	40, 40	23 (16–44)	8	2	0	30 + 1 twin	1	7 (6 singl. + 1 twin)	31 (24–35)	1598 (1538–1935)	CS 27 (90%)	29	PE 15 (37.5%), eclampsia 1, HELLP 1	IUGR 3, duodenal atresia 1, cleft palate with ear anomalies 1	Preterm (34–37 wk) 5, early preterm (28–33 wk) 19, extreme preterm (<28 wk) 5 + 1 twin
Shah [21], 2019, USA	2008, 2352; 12%: 2 preg, 2%: ≥3 preg	29 ± 6.0 (15–44)	691 (29.4%) +63 Ecto. = 754	178 (7.6%)	60 2.6%	637 (27%) + 730 (31%) NR	NR	NR	NR	NR	CS 244 (35.4%)	NR	Ectopic/trophoblastic pregnancies 63 (2.7%)	NR	NR
Hladunewich [22], 2014, Canada	17, 22; 5 W 2 preg	34 ± 4	1 (4.5%)	0	2	19 (86.4%) + 1 twin	9	1 (4.5%)	36 (32–37) IQR	2118 ± 857, LBW 7 (43.8%), VLBW 1 (6.3%)	CS 2 (9%)	10 (53%)	HTN 1, PE 1, hydramnios 1, PROM 2, placental insufficiency 3, chorioamnionitis 1, cervical insufficiency 4	IUGR 3	Preterm (<37 wk) 6, early preterm (<34 wk) 3 + 1 twin, extreme preterm (<28 wk) 1

Table 2: Continued

Author [Ref], publication year, country	N W, preg	Age (years)	Miscar	Abort	Still birth	Live birth	Full term	Neonatal deaths	Gestational age (mean/median)	Birth weight (g)	Mode of delivery	Preterm delivery	Maternal and pregnancy complications	Foetal and neonatal complications	Preterm birth categories
Suarez [23], 2015, Brazil	14, 14	30.4 ± 5.4	0	0	0	14	4 (28.6%)	0	≥37 wk 4, 34–36 + 6 wk 6, 30–33 + 6 wk 2, <30 wk 2	2099 ± 0.0, >2500: 3 (21.4%), <2500: 11 (78.6%)	CS 10 (71.4%)	10 (71.4%)	HTN 4, PE 1, abruption placentas 2, hydramnios 5 (35.7%), preterm labour 6 (42.9%), acute pulmonary oedema 2	IUGR 3 (21.4%)	Late preterm (34–36 wk) 6 (42.9%), early preterm (30–33 wk) 2 (14.3%), extreme preterm (<30 wk) 2 (14.3%)
Piccoli [24], 2014, Italy	23, 23	31 (22–42)	0	0	0	23 + 1 twin	2	2 + 1 twin	30 (26–37)	1200 (590–2250), LBW 8, VLBW 11, ELBW 4, 1 NR	CS 20 1 NR	19 (90.4%) 1 NR	HTN 5, PE 2, PROM 6, hydramnios 2, peritonitis 1, HELLP 1, preterm labour 6	SGA 7, RDS 5, NICU 15, IUGR 1, arm dysplasia 1, hernia 2, patent ductus 2, pneumonia 1, retinitis 1	Preterm (<37 wk) 6, early preterm (<34 wk) 10 + 1 twin, extreme preterm (<28 wk) 3
Jesudason [25], 2014, Australia	73, 77; 3 W ≥2 preg	30 (26–32.3)	10	14	7	46 (60%)	NR	3	33.8 (30.6–37.6) IQR	1750 (1130–2417) IQR	NR	NR	PE 10 (15%), gestational diabetes 1 (1.3%),	SGA 11,	Preterm (34–36.6 wk) NR, early preterm (28–33.6 wk) NR, extreme preterm (<28 wk) (11.4%)
Hadj Sadek [26], 2011, Morocco	8, 11; 2 W ≥2 preg	IQR (15–45) 34.2 ± 6.1 (24–45)	4	1	1	5	1	0	33.6 (30–37) (excluding 1 stillbirth)	2070 ± 618, LBW 4, VLBW 1	CS 1	4	AN 10	IUGR 1, NICU 2, pyelocaliceal dilatation with renal insufficiency 1	Late preterm (33–36 wk) 3, early preterm (<34 wk) 1, extreme preterm (<28 wk) 0

W, women; Preg, pregnancy; wk, week; Miscar, miscarriage; Abort, abortion; Still, stillbirth; HDP, hypertensive disorders of pregnancy; HTN, hypertension; PE, preeclampsia; HELLP: haemolysis, elevated liver enzymes and low platelet count; AN, anaemia; PROM, premature rupture of membranes; CS, Caesarean section; RDS, respiratory distress syndrome; NICU, neonatal intensive care unit; NEC, necrotizing enterocolitis; ASD, atrial septal defect; VSD, ventricular septal defect;
SGA, small for gestational when the birth weight <10th percentile; FGR, foetal growth retardation; IUGR, intrauterine growth restriction; Ecto, ectopic;
LBW, low birth weight (1500–2499 g); VLBW, very low birth weight (1000–1499 g); ELBW, extremely low birth weight <1000 g);
NR, not reported; IQR: interquartile range.

for pooling in nine studies. The causes were primary glomerulonephritis (26.4%), hypertensive nephropathy (19.4%), diabetes (17.7%) and vasculitis (13.8%) (Supplementary data, Table S2).

Haemodialysis was the predominant modality for women renal replacement therapy during pregnancy, in 2551 (92.6%) pregnancies, and only three studies reported 203 (7.4%) pregnancies while on peritoneal dialysis. For women on dialysis who conceived, their time on dialysis before conception ranged from 1 to 192 months (Table 3). Dialysis duration in studies that reported it (mean or median) ranged from 14 to 43 h per week (Supplementary data, Fig. S2, Table 3) with a frequency of 3 to 6 sessions per week for 2 to 6 h per session (Supplementary data, Fig. S3, Table 3). There was only reported an increase in dialysis for patients on peritoneal dialysis. Before dialysis sessions, the blood urea nitrogen (BUN) level before dialysis sessions was reported in only six studies, ranging from 29 to 89 mg/dL. Antihypertensives and erythropoietin were the most cited therapies but reported in only six (42.8%) studies (Table 3).

Pregnancy complications and outcomes

In Table 2 we reported the main maternal and foetal outcomes. There were 402 pregnancies (13 studies) for which data regarding pregnancy complications and outcomes were available. Overall, 68 out of 402 (16.9%) spontaneous miscarriages, 21 out of 402 (5.2%) therapeutic abortions and 26 (8.3%) stillbirths among 313 (stillbirths and live births) were recorded (Fig. 2). The mean or median gestational age at delivery ranged from 25.2 to 36 weeks. There were 61 (17. 7%) cases of polyhydramnios, 3 chorioamnionitis, 3 placental insufficiencies and 3 placental abruptions. Regarding mode of delivery, Caesarean section ranged from 9% to 100% depending on the study. The indications for delivery were reported in 345 pregnancies (12 studies), mostly hypertensive disorders of pregnancy in 59 (17.1%) patients, spontaneous preterm labour in 28 (8.1%), intrauterine growth restriction in 22 (6.5%), premature rupture of membranes in 11 (3.2%), cervical insufficiency in 8 (2.3%), foetal distress in 8 (2.3%) and previous Caesareans in 8 (2.3%) cases.

Maternal complications during pregnancy

Thirteen studies reported maternal complications during pregnancy in 402 pregnancies (Table 2): preeclampsia in 48 (11.9%); hypertension in 31 (7.7%); anaemia in 16 (3.9%); eclampsia in 3 (0.7%); haemolysis, elevated liver enzymes and low platelet counts (HELLP) in 3 (0.7%); gestational diabetes in 2 (0.5%); peritonitis in 1 (0.2%) and cholestasis in 3 (0.7%). This latter maternal complication was reported in only one study [19]. In accordance with the WHO definition of maternal death during pregnancy and childbirth or within 42 days of terminating pregnancy, there were no cases of maternal death reported during this period in the 13 studies included that had data available on maternal complications [27].

Neonatal outcomes and complications

Live births represented 287 (71.4%) out of 402 pregnancies. Birth weight ranged from 590 to 3500 g; Apgar scores at 5 min were reported in only four studies, and ranged from 1 to 10. Full term was reported in 12 studies [33 (10.6%)]. Preterm live birth was the main, most common complication in all studies representing 82.8% of births (range 50%–100%). It was difficult to summarize the categories of prematurity due to lack of information and/or differences in definitions between studies, heterogeneity in cut-offs applied for preterm birth. The need for neonatal intensive care was unreported in seven studies despite the high rate of prematurity. However, in those studies that reported the information it was 97 (65.5%; range 21.4%–100%). Small-for-gestational-age was reported in 70 (32%) neonates and respiratory distress syndrome in 7 (2.4%). There were 22 (7.6%) neonatal deaths among 287 live births and 48 (15.3%) perinatal deaths among 313 total births (stillbirths and live births) (Fig. 2). Malformations were reported in nine infants (four studies). These included one infant with duodenal atresia and one with cleft palate and ear anomalies (both died soon after birth); one with an abdominal hernia (who died after 120 days in the neonatal intensive care unit); and the other six children survived. Other neonatal complications are summarized in Table 2.

DISCUSSION

This systematic review was conducted with the aim of examining recent data on maternal and foetal outcomes in pregnant women with end-stage renal disease on chronic dialysis published over the last decade (2010–20). The total number of pregnancies in this study was 2754 in 2364 patients. This represents an increase compared with previous reviews [28, 29] with, respectively, 90 pregnancies in 82 patients and 574 pregnancies in 543 patients, probably linked to improvements in dialysis conditions over the years thus contributing to improvements in their prognosis [30]. However, for only 402 pregnancies (13 studies) among 2754 were data regarding pregnancy complications and foetal outcomes available because the only larger study, with 2352 pregnancies [21], had a high number of unknown cases, thereby limiting the statistical significance of our results.

In previous studies and reviews, a significant correlation was found between the number of hours of dialysis and the improvement in foetal prognosis like live birth, preterm delivery and small-for-gestational-age [30, 31]. However, there is still great heterogeneity in dialysis schedules between studies and countries. In our review, the duration of dialysis ranged from 14 to 43 h per week, and the maximum frequency was 3 to 6 sessions per week. Peritoneal dialysis was reported in three studies, the number of patients being lower than those on haemodialysis, and it was only reported that there was an increase in dialysis during pregnancy [21, 24, 25, 32, 33].

Only 6 out of 14 studies reported BUN levels. Pre-dialysis BUN levels ranged from 29 to 36 mg/dL with only one study reporting a BUN level of 89 mg/dL. Increasing dialysis dosage reduces pre-dialysis BUN levels in order to maintain near-physiological BUN level, which has been associated with higher gestational age, live birth rates, birth weight, lower rates of maternal hypertension and hydramnios. A pre-dialysis mid-week serum BUN level <35 mg/dL could be used as a threshold for dialysis dose adjustment as it seems to be a reliable criterion for dialysis performance [34–37].

Hypertensive pregnancy disorders remain the main maternal complication, their incidence during pregnancy in our study were preeclampsia in (11.9%), hypertension in (7.7%) and eclampsia in (0.7%). This represents a decrease compared with a previous review (30.2%) [28], through intensified dialysis and improvements in pregnancy monitoring [37–40]. In our study, there were (17.7%) cases of polyhydramnios due to foetal diuresis caused by high placental BUN concentration, representing a decrease compared with a previous systematic review (32%) [28]. That may have been attributed to intensive dialysis [31, 34–37].

In our review, there were 287 (71.4%) live births among 402 pregnancies, varying between studies and ranging from 50% to

Table 3: Time on dialysis before pregnancy, dialysis schedules, pre-dialysis blood urea nitrogen and prescriptions.

Author [Ref], publication year, country	Period of study	*N* W, *N* preg	Time on dialysis before pregnancy (months) mean or median	COD	CBD	Type of dialysis		Dialysis schedule duration and frequency (mean or median)	BUN at delivery (mg/dL)	EPO, iron, vitamin and other drugs
						HD	PD			
Ibarra-Hernandez [13], 2019, Mexico	2013–17	15, 15	NR	2	13	15	0	15.07 ± 3.8 h/wk	34 (29–44)	NR
Luders [14], 2018, Brazil	2000–17	89, 93	24 (1–192) range	47	46	93	0	15.4 ± 4.0 h/wk 6 days/wk, 2.6 ± 0.7 h/day	36.9 ± 9.4	EPO dose 24 000 (4000–48 000) IU/wk, low dose aspirin (before 12 wk), calcium supplementation
Moscoso Solorzano [15], 2019, Ecuador	2014–16	8, 8	11 ± 4	8	0	8	0	24 h/wk	NR	NR
Hirano [16], 2021, Japan	2012–16	15, 19	100.8 ± 87.6	19	0	19	0	26.3 ± 5.1 h/wk, 5.6 ± 0.5 days/wk	FT: 24 ± 10; PB: 34 ± 16	NR
Hoffman [17], 2020, USA	2012–16	10, 10	NR	3 (23%)	7 (77%)	10	0	21.9 ± 4.5 h/wk (18–30) h/wk range	38.1 ± 17.1 highest value	NR
Megahed [18], 2020, Egypt	2011–16	33, 57	93.43 ± 49.4	NR	NR	57	0	24 (20–24) h/wk 4–6 days/wk, 4 ± 0 h/day	NR	NR
Fiedler [19], 2019, Chile	2001–16	11, 13	4 (3–28) range	10 (76.9%)	3 (23.1%)	10	0	24 (19.5–24) h/wk IQR	34 (29–36)	EPO dose 12 000 (6000–12 000) IU/wk, i.v. iron 100 (100–200) mg/wk
Hernández Rivera [20], 2019, Mexico	2002–14	40, 40	0	0	40	40	0	14 (9–15) h/wk 3 days/wk, 3–5 h/day	89 ± 0	Antihypertensive treatment, diuretics
Shah [21], 2019, USA	2005–13	2008, 2352	<12: 436; 12–36: 708; >36: 1208	2352	0	2160 (89.8%)	192 (10.2%)	NR	NR	NR
Hladunewich [22], 2014, Canada	2000–13	17, 22	41 (16–72) IQR	18	4	22	0	43 ± 6 h/wk 6–7 days/w, 6–8 h/day	NR	EPO, i.v. iron, phosphate supplementation, antihypertensive therapy
Suarez [23], 2015, Brazil	2003–12	14, 14	23 ± 15	10 (71.4%)	4 (28.6%)	14	0	NR 5–6 days/wk	NR	EPO, antihypertensive treatment
Piccoli [24], 2014, Italy	2000–12	23, 23	NR	19	4	20	3	24 (12–42) h/wk 4–6 days/wk, 4–6 h/day for 2 PD increase	NR	NR
Jesudason [25], 2014, Australia	2001–11	73, 77	12 (6–33) range	53	24	69	8	NR	NR	NR
Hadj Sadek [26], 2011, Morocco	2000–10	8, 11	76 (2–188) range	11	0	11	0	15.5 (12–16) h/wk 3.5 ± 1.5 days/wk, 4–5 h/day	NR	EPO dose 4000 (2000–6000) IU/wk, oral iron, heparin, antihypertensive treatment

W, women; Preg, pregnancies; FT, full term birth; PB, preterm birth; HD, Haemodialysis; PD, peritoneal dialysis; COD, conception on dialysis; CBD, conception before dialysis; NR, not reported; IQR: interquartile range; EPO: erythropoetin.

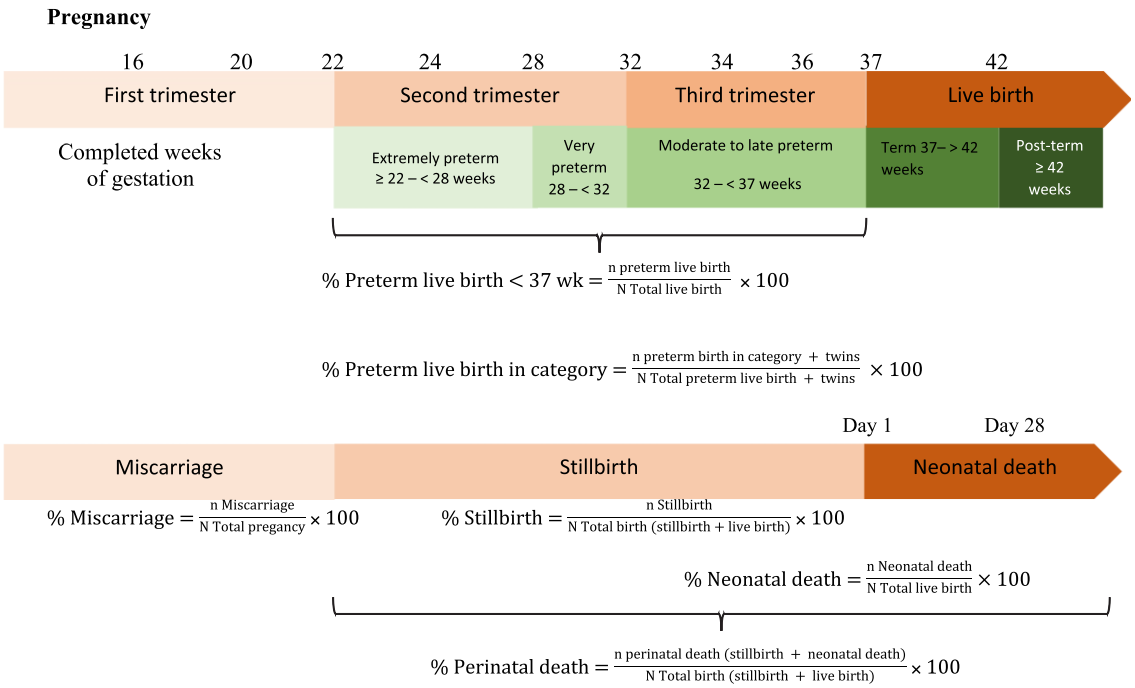


Figure 2: Pregnancy outcomes for international comparison.

100%, probably due to the difference in dialysis schedules between countries [24, 31], socioeconomic status and inequalities regarding access to healthcare around the world [13, 20, 21]. Preterm birth (<37 weeks of gestation) was the main, most common complication in all studies (82.8%), ranging from 50% to 100%, in keeping with other reports [28–31]. This heterogeneity between studies is probably attributed to variations in dialysis intensity provided in different countries and induced delivery due to materno-foetal complications [31].

Birth weight ranged from 590 to 3500 g, but we found heterogeneity of data, and combining it was difficult because results from different studies were in various forms. Some studies presented their results with medians, interquartile range or with minimum and maximum values and other studies reported means and standard deviations, with no claim as to whether their data followed or satisfied the assumptions of normality. Small-for-gestational-age in our systematic review was (20.3%), and intrauterine growth restriction was 6.5%, representing a decrease compared with previous reviews: 32% and 10. 4%, respectively, probably due to an increase in the duration and frequency of dialysis compared with studies of other decades [28, 30, 31].

The lower incidence of neonatal deaths (7.6%) and perinatal deaths (15.3%) over the years, compared with previous reviews of 11.9% and 17.6%, respectively [28], might be attributable to improvements in dialysis, adequate foetal monitoring, and advances in obstetric and neonatal care.

There were improvements in some maternal and foetal outcomes, probably due to more frequent dialysis and the centres' growing experience, adequate foetal monitoring, and advances in obstetric and neonatal care. However, there were still more complications than normal pregnancies due, not only to dialysis, but also to patient profiles (age, obesity, hypertension and diabetes).

In our review, maternal age at conception differed between studies (range 15–45 years). In the general population it has long been established that advanced maternal age alone is a risk factor for several pregnancy complications: gestational diabetes, hypertension, preeclampsia, increased risk of prematurity, death *in utero*, congenital anomalies, risk of placenta praevia and the likelihood of Caesarean section [16, 18, 41]. While adolescent mothers face higher risks of abortion, eclampsia, endometritis and systemic infections, their infants are at greater risk of low birth weight, preterm birth and serious neonatal conditions [13, 18, 38,42].

Information on obesity was present in 5 studies among the 14 included in this review [13, 17, 21, 23, 25] and the incidence ranged from 7.1% to 38.7% among the 2364 women. All these studies apart from one were from the Americas. There two were from North America, two from South America and one from Australia. We know that obesity has begun to increase over the last decades in developed countries, however; obesity is a risk factor for hypertension, preeclampsia and diabetes. In addition, studies on the general population show that the rates of early miscarriage and stillbirth are significantly higher in cases of maternal obesity [39, 40, 43].

Chronic hypertension was reported in 10 of the 14 studies and 146 out of 232 (62.9%) women had chronic hypertension at the start of pregnancy (Supplementary data, Table S2). In the general population, chronic hypertension is well-known for being a major cause of maternal, foetal and neonatal complications such as superimposed preeclampsia, preterm delivery, birth weight <2500 g and perinatal death [44].

For only 6 of the 14 studies, data for women with pre-existing diabetes (Type 1 or Type 2) were available and 24 out of 234 (10.2%) women (Supplementary data, Table S2). In the general population, women with pre-existing diabetes are at a greater risk of pregnancy complications including birth defects, preeclampsia and preterm birth [45, 46].

Considering the risk of pregnancy complications in dialysis, women of childbearing age should wait for a kidney transplant

provided that the transplant is not contraindicated, or refused by the patient, or if the patient's maternal age is not too advanced and the time for access to the graft is not long because, for kidney transplant recipients, pregnancy outcomes are considered better [31, 47].

Limitations

Our study has certain limitations. First, this systematic review was based on case series and retrospective studies representing Level 3 evidence. Second, most of the studies were single-centred, with small numbers of patients included. Third, due to the differences between countries and periods of study, we observed high heterogeneity of data on patient characteristics, duration of dialysis and management regimens. Fourth, due to lack of data, we focused on patients on dialysis without distinguishing those who were already on dialysis before the start of pregnancy from those who started dialysis during pregnancy. Finally, as some studies had no control group, we were unable to combine data into a meta-analysis and, at the same time, we need data on the number of pregnancies in the general population to compare.

There were considerable variations between studies regarding the definition of prematurity and low birth weight categories. Due to the limits of pooling and the heterogeneity of data, we propose standardizing the definition of the indicators and the way they are calculated (same numerators/same denominators). Having the same denominator between studies would facilitate data-pooling and international comparisons [27, 48]. In addition, we suggest that results be expressed in medians since many items may not have a normal distribution [49]. Lastly, we ask authors to always report the specificity of the dialysis schedule, the dialysis membrane technique, the evolution of dialysis dosage according to time of pregnancy and the medium-term follow-up of infants.

We conclude our work with a summary (Fig. 2) in accordance with the WHO ICD-10 definitions and international statistical classification of diseases and related health problems, to serve as a comprehensive guide for performing calculations on different indicators, for a common language in future studies on pregnancy in chronic dialysis [48, 50–52].

CONCLUSION

Presumably, there is an increase in the frequency of pregnancy among patients with end-stage chronic kidney disease treated by chronic dialysis considering both the increase in the number of publications and the total number of pregnancies reported in such publications. There were improvements in some maternal and foetal outcomes attributed to progress in dialysis treatment, adequate foetal monitoring, and advances in obstetric and neonatal care. However, our review demonstrates that the practice of treating pregnant women on dialysis differs significantly between countries. These findings highlight the need to standardize the definition of outcomes and care for pregnant dialysis patients. Larger studies on a population basis are required in order to be able to estimate the incidence of pregnancy in dialysis patients.

SUPPLEMENTARY DATA

Supplementary data are available at *ckj* online.

ACKNOWLEDGEMENTS

We thank Teresa Sawyers, British medical writer, at the B.E.S.P.I.M. for her help with revising the manuscript.

DATA AVAILABILITY STATEMENT

The articles used in this review are available in the present article. Access to full publication is under the authorities of each publisher.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no conflicts of interest.

REFERENCES

1. Hou S. Historical perspective of pregnancy in chronic kidney disease. *Adv Chronic Kidney Dis* 2007;**14**:116–8. http://dx.doi.org/10.1053/j.ackd.2007.01.001.
2. Moranne O, Samouelian V, Lapeyre F *et al*. Pregnancy and hemodialysis. *Nephrologie* 2004;**25**:287–92. https://www.ncbi.nlm.nih.gov/pubmed/15584638.
3. Sachdeva M, Barta V, Thakkar J *et al*. Pregnancy outcomes in women on hemodialysis: a national survey. *Clin Kidney J* 2017;**10**:276–81.
4. Le Stang M-B, Belenfant X. Pregnancy in women on dialysis: a French cohort study. *Nephrol Dial Transplant* 2015;**30**: iii327. http://dx.doi.org/10.1093/ndt/gfv183.67.
5. Shahir AK, Briggs N, Katsoulis J *et al*. An observational outcomes study from 1966-2008, examining pregnancy and neonatal outcomes from dialysed women using data from the ANZDATA registry. *Nephrology* 2013;**18**:276–84. http://dx.doi.org/10.1111/nep.12044.
6. Tangren J, Nadel M, Hladunewich M. Pregnancy and end-stage renal disease. *Blood Purif* 2018;**45**:194–200. http://dx.doi.org/10.1159/000485157.
7. Barua M, Hladunewich M, Keunen J *et al*. Successful pregnancies on nocturnal home hemodialysis. *Clin J Am Soc Nephrol* 2008;**3**:392–6. http://dx.doi.org/10.2215/CJN.04110907.
8. Normand G, Xu X, Panaye M *et al*. Pregnancy outcomes in French hemodialysis patients. *Am J Nephrol* 2018;**47**:219–27. http://dx.doi.org/10.1159/000488286.
9. Shamseer L, Moher D, Clarke M *et al*. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015: elaboration and explanation. *BMJ* 2015;**349**:g7647. http://dx.doi.org/10.1136/bmj.g7647.
10. Stroup DF, Berlin JA, Morton SC *et al*. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis of Observational Studies in Epidemiology (MOOSE) group. *JAMA* 2000;**283**:2008–12. http://dx.doi.org/10.1001/jama.283.15.2008.
11. Wells GA, Shea B, O'Connell D *et al*. The Newcastle-Ottawa Scale (NOS) for assessing the quality of nonrandomised studies in metaanalyses. Available from http://www.ohri.ca/programs/clinical epidemiology/oxford.asp (10 February 2019, date last accessed)
12. McGinn T, Wyer PC, Newman TB *et al*. Tips for learners of evidence-based medicine, 3: measures of observer variability (kappa statistic). *Can Med Assoc J* 2004;**171**:1369–73. http://dx.doi.org/10.1503/cmaj.1031981.
13. Ibarra-Hernandez M, Alcantar-Vallin ML, Soto-Cruz A *et al*. Challenges in managing pregnancy in underserved women

with chronic kidney disease. *Am J Nephrol* 2019;**49**:386–96. http://dx.doi.org/10.1159/000499964.
14. Luders C, Titan MC, Kahhale S *et al*. Risk factors for adverse fetal outcome in hemodialysis pregnant women. *Kidney Int Rep* 2018;**3**:1077–88. http://dx.doi.org/10.1016/j.ekir.2018.04.013.
15. Moscoso Solorzano GT, Farfan Jimenez AG. Pregnancy outcomes and chronic kidney disease: Ecuadorian single center experience. *Clin Nephrol* 2019;**92**:319–24. http://dx.doi.org/10.5414/CN109130.
16. Hirano H, Ueda T, Tani H *et al*. Pregnancy and delivery in women receiving maintenance hemodialysis in Japan: analysis of potential risk factors for neonatal and maternal complications. *J Nephrol* 2021;**34**:1599–609. http://dx.doi.org/10.1007/s40620-021-01146-3.
17. Hoffman M, Sibai B. Dialysis in pregnancy: role of the underlying cause of renal failure on peripartum outcomes. *Am J Perinatol* 2020;**37**:570–6.
18. Farouk Megahed A, El Kannishy G, El Azawy H *et al*. Pregnancy outcomes in Egyptian women on maintenance hemodialysis: a multicenter observational study. *Asian J Med Health* 2020;**18**:1–17. http://dx.doi.org/10.9734/ajmah/2020/v18i1030247.
19. Fiedler ZÚ, Sanhueza VME, Toro CL. Pregnancy during chronic hemodialysis. A series of cases. *Rev Med Chil* 2019;**147**:709–17.
20. Hernández Rivera JCH, Pérez López MJ, Corzo Bermúdez CH *et al*. Delayed initiation of hemodialysis in pregnant women with chronic kidney disease: logistical problems impact clinical outcomes. An experience from an emerging country. *J Clin Med* 2019;**8**:475. http://dx.doi.org/10.3390/jcm8040475.
21. Shah S, Christianson AL, Meganathan K *et al*. Racial differences and factors associated with pregnancy in ESKD patients on dialysis in the United States. *J Am Soc Nephrol* 2019;**30**:2437–48. http://dx.doi.org/10.1681/ASN.2019030234.
22. Hladunewich MA, Hou S, Odutayo T *et al*. Intensive hemodialysis associate with improved pregnancy outcomes: a Canadian and United States cohort comparison. *J Am Soc Nephrol* 2014;**25**:1103–9. http://dx.doi.org/10.1681/ASN.2013080825.
23. Bracco Suarez MB, Costa ML, Parpinelli MA *et al*. Pregnancy in women undergoing hemodialysis: case series in a Southeast Brazilian reference center. *Rev Bras Ginecol Obstet* 2015;**37**:5–9. http://dx.doi.org/10.1590/SO100-720320140005130.
24. Piccoli GB, Cabiddu G, Daidone G *et al*. The children of dialysis: live-born babies from on-dialysis mothers in Italy—an epidemiological perspective comparing dialysis, kidney transplantation and the overall population. *Nephrol Dial Transplant* 2014;**29**:1578–86. http://dx.doi.org/10.1093/ndt/gfu092.
25. Jesudason S, Grace BS, McDonald SP. Pregnancy outcomes according to dialysis commencing before or after conception in women with ERSD. *Clin J Am Soc Nephrol* 2014;**9**:143–9. http://dx.doi.org/10.2215/CJN.03560413.
26. Hadj Sadek B, Kejji S, Rhou H *et al*. Pregnancy in chronic hemodialysis patients. *J Gynecol Obstet Biol Reprod (Paris)* 2011;**40**:452–9. http://dx.doi.org/10.1016/j.jgyn.2011.04.003.
27. WHO. *ICD-10: international statistical classificiation of diseases and related health problems: tenth revision*. 2nd edn. http://www.who.int/classifications/icd/ICD-10_2nd_ed_volume2.pdf (2004) (9 October 2011, date last accessed).
28. Yang LY, Thia EW, Tan LK. Obstetric outcomes in women with end-stage renal disease on chronic dialysis: a review. *Obstet Med* 2010;**3**:48–53. http://dx.doi.org/10.1258/om.2010.100001.
29. Piccoli GB, Conijn A, Consiglio V *et al*. Pregnancy in dialysis patients: is the evidence strong enough to lead us to change our counseling policy? *Clin J Am Soc Nephrol* 2010;**5**:62–71. http://dx.doi.org/10.2215/CJN.05660809.
30. Piccoli GB, Minelli F, Versino E *et al*. Pregnancy in dialysis patients in the new millennium: a systematic review and meta-regression analysis correlating dialysis schedules and pregnancy outcomes. *Nephrol Dial Transplant* 2016;**31**:1915–34. http://dx.doi.org/10.1093/ndt/gfv395.
31. Hladunewich M, Schatell D. Intensive dialysis and pregnancy. *Hemodial Int* 2016;**20**:339–48. http://dx.doi.org/10.1111/hdi.12420.
32. Seong Lim CT, Wah FK. Pregnancy and peritoneal dialysis: an updated review. *EMJ Nephrol* 2018;**6**:74–84.
33. Batarse RR, Steiger RM, Guest S. Peritoneal dialysis prescription during the third trimester of pregnancy. *Perit Dial Int* 2015;**35**:128–34. http://dx.doi.org/10.3747/pdi.2013.00229.
34. Manisco G, Potì' M, Maggiulli G *et al*. Pregnancy in end-stage renal disease patients on dialysis: how to achieve a successful delivery. *Clin Kidney J* 2015;**8**:293–9. http://dx.doi.org/10.1093/ckj/sfv016.
35. Luders C, Castro MC, Titan SM *et al*. Obstetric outcome in pregnant women on long-term dialysis: a case series. *Am J Kidney Dis* 2010;**56**:77–85. http://dx.doi.org/10.1053/j.ajkd.2010.01.018.
36. Haase M, Morgera S, Bamberg CH *et al*. A systematic approach to managing pregnant dialysis patients-the importance of an intensified haemodiafiltration protocol. *Nephrol Dial Transplant* 2005;**20**:2537–42. http://dx.doi.org/10.1093/ndt/gfi044.
37. Asamiya Y, Otsubo S, Matsuda Y *et al*. The importance of low blood urea nitrogen levels in pregnant patients undergoing hemodialysis to optimize birth weight and gestational age. *Kidney Int* 2009;**75**:1217–22. http://dx.doi.org/10.1038/ki.2009.48.
38. Campbell B, Gilmore K, Kaidbey M *et al*. *Motherhood in Childhood Facing the challenge of adolescent pregnancy*. United Nations Population Fund https://www.unfpa.org 〉 pub-pdf 〉 EN-SWOP2013 (September 25, 2022, date last accessed).
39. Cnattingius S, Bergström R, Lipworth L *et al*. Prepregnancy weight and the risk of adverse pregnancy outcomes. *N Engl J Med* 1998;**338**:147–52. http://dx.doi.org/10.1056/NEJM199801153380302.
40. Weiss JL, Malone FD, Emig D *et al*. Obesity, obstetric complications and cesarean delivery rate–a population-based screening study. *Am J Obstet Gynecol* 2004;**190**:1091–7. http://dx.doi.org/10.1016/j.ajog.2003.09.058.
41. Kushner DH. Fertility in women after age forty-five. *Int J Fertil* 1979;**24**:289–90. https://www.ncbi.nlm.nih.gov/pubmed/45103.
42. Sedgh G, Finer LB, Bankole A *et al*. Adolescent pregnancy, birth, and abortion rates across countries: levels and recent trends. *J Adolesc Health* 2015;**56**:223–30. http://dx.doi.org/10.1016/j.jadohealth.2014.09.007.
43. Kristensen J, Vestergaard M, Wisborg K *et al*. Pre-pregnancy weight and the risk of stillbirth and neonatal death. *BJOG* 2005;**112**:403–8. http://dx.doi.org/10.1111/j.1471-0528.2005.00437.x.
44. Bramham K, Parnell B, Nelson-Piercy C *et al*. Chronic hypertension and pregnancy outcomes: systematic review and meta-analysis. *BMJ* 2014;**348**:g2301. http://dx.doi.org/10.1136/bmj.g2301.
45. Gojnic M, Todorovic J, Stanisavljevic D *et al*. Maternal and fetal outcomes among pregnant women with diabetes. *Int*

J Environ Res Public Health 2022;**19**:3684. http://dx.doi.org/10.3390/ijerph19063684.

46. Ringholm L, Damm P, Mathiesen ER. Improving pregnancy outcomes in women with diabetes mellitus: modern management. *Nat Rev Endocrinol* 2019;**15**:406–16. http://dx.doi.org/10.1038/s41574-019-0197-3.
47. Boulay H, Mazaud-Guittot S, Supervielle J *et al*. Maternal, foetal and child consequences of immunosuppressive drugs during pregnancy in women with organ transplant: a review. *Clin Kidney J* 2021;**14**:1871–8. http://dx.doi.org/10.1093/ckj/sfab049.
48. WHO: recommended definitions, terminology and format for statistical tables related to the perinatal period and use of a new certificate for cause of perinatal deaths. Modifications recommended by FIGO as amended October 14, 1976. *Acta Obstet Gynecol Scand* 1977;**56**:247–53. https://www.ncbi.nlm.nih.gov/pubmed/560099.
49. Wan X, Wang W, Liu J *et al*. Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. *BMC Med Res Method* 2014;**14**:135. http://dx.doi.org/10.1186/1471-2288-14-135.
50. Lawn JE, Blencowe H, Pattinson R *et al*. Stillbirths: where? When? Why? How to make the data count? *Lancet North Am Ed* 2011;**377**:1448–63. http://dx.doi.org/10.1016/S0140-6736(10)62187-3.
51. Blencowe H, Cousens S, Oestergaard MZ *et al*. National, regional, and worldwide estimates of preterm birth rates in the year 2010 with time trends since 1990 for selected countries: a systematic analysis and implications. *Lancet North Am Ed* 2012;**379**:2162–72. http://dx.doi.org/10.1016/S0140-6736(12)60820-4.
52. Lawn JE, Blencowe H, Oza S *et al*. Every newborn: progress, priorities, and potential beyond survival. *Lancet North Am Ed* 2014;**384**:189–205. http://dx.doi.org/10.1016/S0140-6736(14)60496-7.