UK Renal Registry 16th Annual Report: Chapter 9 Adequacy of Haemodialysis in UK Adult Patients in 2012: National and Centre-specific Analyses

Catriona Shaw[a], Retha Steenkamp[a], Andrew Davenport[b]

[a]UK Renal Registry, Bristol, UK; [b]Royal Free Hospital, London, UK

Key Words
Adequacy · Haemodialysis · Urea reduction ratio

Summary

- Data suitable for urea reduction ratio (URR) analyses were available in 15,286 (75.2%) of the 20,332 patients receiving haemodialysis (HD) in the UK on the 30/9/2012.
- In 2012, 88% of prevalent HD patients achieved a URR >65%. The between centre range of prevalent patients achieving this target was wide (69.7–100%).
- The median URR in 2012 was 75%.
- URR was greater in those with longer dialysis vintage. Ninety one percent of patients who had survived on renal replacement therapy (RRT) for more than two years achieved a URR >65% compared with only 74% of those on RRT for only six months.
- Large variation between centres in the percentage of patients achieving the UK Renal Association's (RA) URR guideline persists. The UK Renal Registry (UKRR) will explore a possible move to reporting Kt/V combined with residual renal function.

Introduction

Amongst patients with established renal failure (ERF), the delivered dose of HD is an important predictor of outcome [1] and has been shown to influence survival [2–4]. The delivered dose of HD depends on treatment (duration and frequency of dialysis, dialyser size, dialysate and blood flow rate) and patient characteristics (size, weight, haematocrit and vascular access) [5]. The two widely accepted measures of urea clearance are Kt/V, the ratio between the product of urea clearance (K, in ml/min) and dialysis session duration (t, in minutes) divided by the volume of distribution of urea in the body (V, in ml) and URR which is derived solely from the percentage fall in serum urea (URR) during a dialysis treatment. Whilst Kt/V is a more accurate descriptor of urea clearance, its calculation is more complex and requires additional data items not commonly reported by most UK renal centres [6, 7]. The UKRR has historically presented analyses based on URR rather than Kt/V for comparative audit of haemodialysis adequacy as these data are more widely available.

Based on published evidence, clinical practice guidelines have been developed by various national and regional organisations [8–11]. There is considerable uniformity between them with regard to the recommendations for minimum dose of dialysis although there are differences in the methodology advised. The main objective of this chapter is to determine the extent to which patients undergoing HD treatment for established renal failure in the UK received the dose of HD, as measured by URR, recommended in the UK RA current clinical practice guidelines [9].

Methods

Seventy-one renal centres in the UK submitted data electronically to the UKRR on a quarterly basis [12]. The majority of these centres have satellite units but for the purposes of this study the data from the renal centres and their associated satellite units were amalgamated. However, because not all centres report frequency of HD, it is possible that data from a small number of patients receiving HD at a different frequency were included in the analyses. Data from two groups of patients were analysed. Firstly, analysis was undertaken using data from the prevalent adult HD patient population as of the 30th September 2012. For this analysis, data for URR were taken from the 3rd quarter of 2012 unless that data point was missing in which case data from the 2nd quarter were taken. The prevalent population only included patients receiving HD who were alive on September 30th 2012. This change in the methodology from using data from the 4th quarter of the year to the 3rd quarter was because many centres reported a dialysis frequency of less than 3 times a week in the 4th quarter. This could be due to changes in dialysis patterns during the December holiday season, or due to some inaccuracy in the data on the part of some renal centres. Data from those patients who had died before that date have not been included in the analysis. The second analysis involved adult incident patients who had commenced treatment with HD during 2011. For these patients, analysis was undertaken using the last recorded URR in the quarter in which the patient had started dialysis. The incident HD patient cohort was followed up for one year and the last recorded URR in the quarter after one year follow-up was used for this analysis.

Data from patients known to be receiving more or less than thrice weekly HD were omitted from analysis for both the incident and prevalent population. Patients whose data recording for the number of dialysis sessions per week were missing, were assumed to be dialysing thrice weekly. Home HD patients were excluded from the analysis.

Analyses of the data from both groups of patients included calculation of the median URR and of the proportion of patients who had achieved the RA guideline (as outlined below) in each of the renal centres as well as for the country as a whole. This year the median URR and proportion of patients who achieved the RA guideline were also calculated separately for males and females. The number of dialysis sessions per week and the time per dialysis session is new in this year's report and is shown by renal centre. The nine centres in Scotland do not provide data on number of dialysis sessions per week and the time per dialysis session to the UKRR and are not included in these analyses.

All patients with data were included in the statistical analyses at a national level, although centres with fewer than 20 patients, or providing less than 50% data completeness were excluded from the comparison between centres. The number preceding the centre name in each figure indicates the percentage of missing data for that centre.

The UK RA clinical practice guidelines [9] in operation at the time these data were collected were as follows:

HD should take place at least three times per week in nearly all patients. Reduction of dialysis frequency to twice per week because of insufficient dialysis facilities is unacceptable.

Every patient receiving thrice weekly HD should have consistently:

- ***either URR >65%***
- ***or equilibrated Kt/V (eKt/V) of >1.2 (or single pool Kt/V of >1.3) calculated from pre- and post-dialysis urea values, duration of dialysis and weight loss during dialysis).***

To achieve a URR above 65% or eKt/V above 1.2 consistently in the vast majority of the HD population clinicians should aim for a minimum target URR of 70% or minimum eKt/V of 1.4 in individual patients.

The duration of thrice weekly HD in adult patients with minimal residual renal function should not be reduced below 4 hours without careful consideration.

Patients receiving HD twice weekly for reasons of geography should receive a higher sessional dose of HD. If this

cannot be achieved, then it should be recognised that there is a compromise between the practicalities of HD and the patient's long-term health.

Measurement of the 'dose' or 'adequacy' of HD should be performed monthly in all hospital HD patients and may be performed less frequently in home HD patients. All dialysis units should collect and report this data to their regional network and the UKRR.

Post-dialysis blood samples should be collected either by the slow-flow method, the simplified stop-flow method, or the stop dialysate flow method. The method used should remain consistent within renal units and should be reported to the Registry.

The RA clinical practice guidelines for HD dose apply specifically to patients undergoing thrice weekly HD. In these patients it is recommended that blood for biochemical measurement (including pre-dialysis urea for URR) should be taken before the mid-week dialysis session [9].

Results

Data completeness

Data providing HD dose (URR) were available from 63 of the 71 renal centres which submitted data to the UKRR (table 9.1). Data were available for 75.2% ($n = 15{,}286$) of the total prevalent population ($n = 20{,}332$) treated with HD who met the inclusion criteria for these analyses.

Completeness in the 63 centres reporting URR data was generally good, with 49 centres reporting data on more than 90% of patients. Three centres reported URR data on less than 50% of prevalent patients (Reading, Newcastle and Sunderland). URR data were not received from eight centres (Brighton, London Barts, London Kings, London Royal Free, London St Georges, Liverpool Aintree, Liverpool Royal Infirmary and Wirral).

Several centres had a reduction in the completeness of URR data submitted to the UKRR in 2012 compared with 2010 (data not shown). These changes may represent changes in data extraction, or a move by centres to utilising Kt/V rather than URR as the preferred measure of dialysis dose.

Of the total incident patient population ($n = 4{,}387$) who started HD during 2011 and meeting the inclusion criteria for URR analyses, 47.0% ($n = 2{,}062$) had URR data available during the first quarter of treatment.

Percentage completeness of data returns on the number of HD sessions varied across centres (table 9.2). Ten centres in England and two centres in Wales returned no data on this variable. All centres in Northern Ireland returned over 88% data.

For those centres that did return data, three dialysis sessions a week was most prevalent, although several centres reported >10% of the HD population undergoing HD for more or less than three sessions. For example, Salford reported 22.9% of their prevalent haemodialysis population having more than three sessions a week whereas Southend reported that 13.3% and Bradford 28.6% of their population in 2012 had fewer than three sessions per week respectively.

Table 9.1. Percentage completeness of URR data returns for prevalent patients on HD by centre, on 30/9/2012

Centre	% completeness	Centre	% completeness
Abrdn	99.5	L Rfree	0.0
Airdrie	100.0	L St.G	0.0
Antrim	99.2	L West	94.7
B Heart	99.5	Leeds	99.6
B QEH	94.8	Leic	99.2
Bangor	100.0	Liv Ain	0.0
Basldn	95.5	Liv RI	0.0
Belfast	95.8	M RI	51.1
Bradfd	96.8	Middlbr	97.2
Brightn	0.0	Newc	1.7
Bristol	100.0	Newry	87.1
Camb	96.8	Norwch	96.3
Cardff	94.0	Nottm	93.7
Carlis	100.0	Oxford	75.3
Carsh	86.8	Plymth	97.4
Chelms	98.1	Ports	95.8
Clwyd	94.3	Prestn	82.9
Colchr	89.6	Redng	3.2
Covnt	98.1	Salford	59.1
D & Gall	100.0	Sheff	94.4
Derby	94.3	Shrew	96.7
Donc	95.4	Stevng	98.6
Dorset	93.7	Sthend	97.8
Dudley	91.6	Stoke	99.6
Dundee	99.4	Sund	1.8
Dunfn	98.6	Swanse	55.1
Edinb	99.6	Truro	69.5
Exeter	98.8	Ulster	97.8
Glasgw	98.7	West NI	95.0
Glouc	100.0	Wirral	0.0
Hull	97.7	Wolve	88.2
Inverns	98.6	Wrexm	96.2
Ipswi	100.0	York	99.2
Kent	92.8	**England**	**71.6**
Klmarnk	100.0	**N Ireland**	**95.4**
L Barts	0.0	**Scotland**	**99.3**
L Guys	73.3	**Wales**	**82.5**
L Kings	0.0	**UK**	**75.2**

Table 9.2. Percentage completeness for the number of dialysis sessions for prevalent patients on HD by centre, on 30/9/2012

Centre	Percentage completeness	Percentage		
		<3 sessions	3 sessions	>3 sessions
England				
B Heart	89.5	5.7	93.4	0.9
B QEH	0.0			
Basldn	97.9	2.9	93.5	3.6
Bradfd	3.7	28.6	71.4	0.0
Brightn	99.3	0.0	99.7	0.3
Bristol	100.0	3.3	96.3	0.5
Camb	99.4	12.0	85.8	2.2
Carlis	86.7	9.6	90.4	0.0
Carsh	0.0			
Chelms	100.0	8.7	90.4	0.9
Colchr	99.1	0.0	100.0	0.0
Covnt	2.2	0.0	100.0	0.0
Derby	89.8	0.6	99.4	0.0
Donc	99.4	1.3	98.7	0.0
Dorset	98.8	2.9	96.7	0.4
Dudley	97.3	3.5	96.5	0.0
Exeter	99.7	2.0	96.0	2.0
Glouc	0.0			
Hull	2.9	11.1	88.9	0.0
Ipswi	86.8	6.1	93.9	0.0
Kent	98.2	6.0	92.9	1.2
L Barts	0.0			
L Guys	0.0			
L Kings	0.0			
L Rfree	0.0			
L St.G	67.4	0.6	99.4	0.0
L West	45.5	0.7	98.4	1.0
Leeds	15.7	2.9	95.7	1.4
Leic	98.7	0.4	99.6	0.0
Liv Ain	100.0	1.9	96.8	1.3
Liv RI	97.9	0.9	90.3	8.8
M RI	51.6	1.4	97.2	1.4
Middlbr	15.5	0.0	100.0	0.0
Newc	99.2	1.3	98.7	0.0
Norwch	98.2	2.5	96.0	1.4
Nottm	99.4	0.6	99.4	0.0
Oxford	0.0			
Plymth	0.0			
Ports	99.2	5.0	93.3	1.7
Prestn	0.0			
Redng	100.0	0.4	99.6	0.0
Salford	99.7	0.6	76.5	22.9
Sheff	99.2	3.1	96.9	0.0
Shrew	100.0	5.0	93.8	1.3
Stevng	98.4	5.2	92.6	2.2
Sthend	99.1	13.3	86.7	0.0
Stoke	99.6	0.4	97.8	1.8
Sund	98.9	0.0	91.1	8.9
Truro	92.4	12.4	83.5	4.1
Wirral	92.4	2.5	87.4	10.1
Wolve	10.7	0.0	100.0	0.0
York	38.7	0.0	97.8	2.2

Table 9.2. Continued

Centre	Percentage completeness	Percentage		
		<3 sessions	3 sessions	>3 sessions
N Ireland				
Antrim	99.2	0.8	99.2	0.0
Belfast	88.5	0.6	98.2	1.2
Newry	97.8	7.8	92.2	0.0
Ulster	96.8	1.1	97.8	1.1
West NI	98.4	0.0	95.2	4.8
Wales				
Bangor	77.6	7.7	92.3	0.0
Cardff	0.0			
Clwyd	94.4	3.0	97.0	0.0
Swanse	0.0			
Wrexm	100.0	1.2	97.5	1.2
England	**54.2**	**2.9**	**94.9**	**2.2**
N Ireland	**95.2**	**1.7**	**96.8**	**1.5**
Wales	**21.7**	**3.5**	**96.0**	**0.5**
E, W & NI	**53.9**	**2.9**	**95.0**	**2.1**

Blank cells denote no data returned by that centre

Wide between centre variation in completeness of data on dialysis session time was also evident (table 9.3). In centres that reported data the most frequently reported dialysis session length was 3–5 hours.

Achieved URR

For prevalent patients, the median URR (75.0% for UK, centre range 70.5–81.0%) and percentage of patients attaining the RA guideline of a URR >65% (88.4% for the UK; centre range 69.7–100%) are shown in figures 9.1a and figure 9.2 respectively. The median URR in women was 78.0% (95% CI 73.0–82.0%) compared with a UK median in men of 74.0% (95% CI 69.0–78.0%) (figures 9.1b, 9.1c).

There continued to be variation between renal centres in the percentage of prevalent patients with a URR of >65%, with 21 centres attaining the RA clinical practice guideline in >90% of patients, 38 centres attaining the guideline in 70–90% of patients and one centre in less than 70% of patients (figure 9.2). There has been an improvement compared with 2010, when five centres reported fewer than 70% of their patients with a URR of >65%.

Changes in URR over time

The change in the percentage attainment of the current RA clinical practice guidelines (URR >65%) and the median URR for the UK from 2000 to 2012 is shown in figure 9.3. The proportion of patients attaining the RA guideline increased from 68.8% to 88.3% whilst the median URR has risen from 69.0% to 75.0% during the same time period. There has been no substantial change in the median URR between 2009 and 2012 in the UK.

Variation of achieved URR with time on dialysis

The proportion of patients who attained the RA guideline for HD was greater in those who had been on RRT for the longest time (figure 9.4). In 2012, of those dialysed for less than 6 months, 74% had a URR >65%, whilst 91% of patients who had survived and continued on RRT for more than two years attained the guideline target. In all strata of time on dialysis, there has been an improvement in the proportion of patients receiving the target dose of HD over the last 13 years.

The median URR during the first quarter of starting HD treatment of the incident HD population in the UK in 2011 was 67.5% (centre range 58.0–76.0%) (figure 9.5a). At the end of one year for this incident cohort, the median URR was higher and more uniform across renal centres (median URR 74.0%, centre range 69.0–80.0%) (figure 9.5b).

Table 9.3. Percentage completeness for time per dialysis session for prevalent patients on HD by centre, on 30/9/2012

Centre	Percentage completeness	Percentage per dialysis session		
		<3.5 hours	3.5–5 hours	5+ hours
England				
B Heart	83.1	4.3	92.0	3.7
B QEH	0.0			
Basldn	97.9	13.0	86.3	0.7
Bradfd	98.4	8.2	91.9	0.0
Brightn	97.7	3.4	96.6	0.0
Bristol	100.0	5.9	94.2	0.0
Camb	0.0			
Carlis	86.7	7.7	92.3	0.0
Carsh	0.0			
Chelms	100.0	9.6	90.4	0.0
Colchr	99.1	1.0	99.1	0.0
Covnt	7.8	44.0	56.0	0.0
Derby	89.8	1.3	98.7	0.0
Donc	99.4	12.4	87.6	0.0
Dorset	98.8	9.0	91.0	0.0
Dudley	97.3	6.3	93.7	0.0
Exeter	99.7	20.3	79.4	0.3
Glouc	0.0			
Hull	2.9	11.1	88.9	0.0
Ipswi	86.8	3.0	97.0	0.0
Kent	98.2	14.6	85.4	0.0
L Barts	0.0			
L Guys	18.5	0.0	100.0	0.0
L Kings	0.0			
L Rfree	0.0			
L St.G	61.8	0.0	100.0	0.0
L West	45.9	3.1	94.8	2.1
Leeds	100.0	8.3	91.7	0.0
Leic	91.9	2.6	97.0	0.4
Liv Ain	100.0	15.6	84.4	0.0
Liv RI	100.0	11.0	88.7	0.3
M RI	50.1	1.9	97.6	0.5
Middlbr	100.0	28.2	71.8	0.0
Newc	99.2	11.4	87.3	1.3
Norwch	98.2	22.3	77.7	0.0
Nottm	16.4	7.3	92.7	0.0
Oxford	0.0			
Plymth	0.0			
Ports	0.0			
Prestn	0.9	0.0	100.0	0.0
Redng	91.3	1.3	98.3	0.4
Salford	97.2	11.1	88.9	0.0
Sheff	82.1	56.3	43.3	0.5
Shrew	99.4	25.8	74.2	0.0
Stevng	99.5	60.8	38.9	0.3
Sthend	99.1	23.8	76.2	0.0
Stoke	100.0	6.2	93.8	0.0
Sund	87.8	8.8	91.2	0.0
Truro	97.7	28.1	71.9	0.0
Wirral	94.2	16.7	81.5	1.9
Wolve	9.6	7.7	92.3	0.0
York	98.3	6.8	93.2	0.0

Table 9.3. Continued

Centre	Percentage completeness	Percentage per dialysis session		
		<3.5 hours	3.5–5 hours	5+ hours
N Ireland				
Antrim	98.4	0.8	99.2	0.0
Belfast	89.1	11.1	88.9	0.0
Newry	97.8	8.9	91.1	0.0
Ulster	96.8	3.3	96.7	0.0
West NI	98.4	11.3	88.7	0.0
Wales				
Bangor	77.6	11.5	88.5	0.0
Cardff	0.0			
Clwyd	94.4	29.9	70.2	0.0
Swanse	0.0			
Wrexm	100.0	3.7	96.3	0.0
England	**52.4**	**13.8**	**85.8**	**0.5**
N Ireland	**95.2**	**7.5**	**92.5**	**0.0**
Wales	**21.7**	**14.5**	**85.5**	**0.0**
E, W & NI	**52.3**	**13.4**	**86.2**	**0.4**

Blank cells denote no data returned by that centre

Discussion

The dose of delivered HD is recognised as having an important influence on outcome in established renal failure (ERF) patients treated with low flux HD. Survival has been shown to depend on achieving a minimum urea clearance target [1–3]. It is therefore reassuring that the proportion of UK patients achieving the RA guideline for URR has increased in the last decade, with 88.4% of the HD population achieving the URR guideline in 2012, with a median URR of 75.0%. This increment will not only reflect improvements in practice and delivery of dialysis, but also enhanced coverage and quality of the data collected by the UKRR and renal centres over the years.

Post hoc analyses of the HEMO study and observational studies have suggested that women may benefit from a higher dialysis dose than men [12, 13]. Current RA guidelines do not differentiate on the basis of gender [9]. It is an interesting observation that the UK median URR achieved in women was higher than in

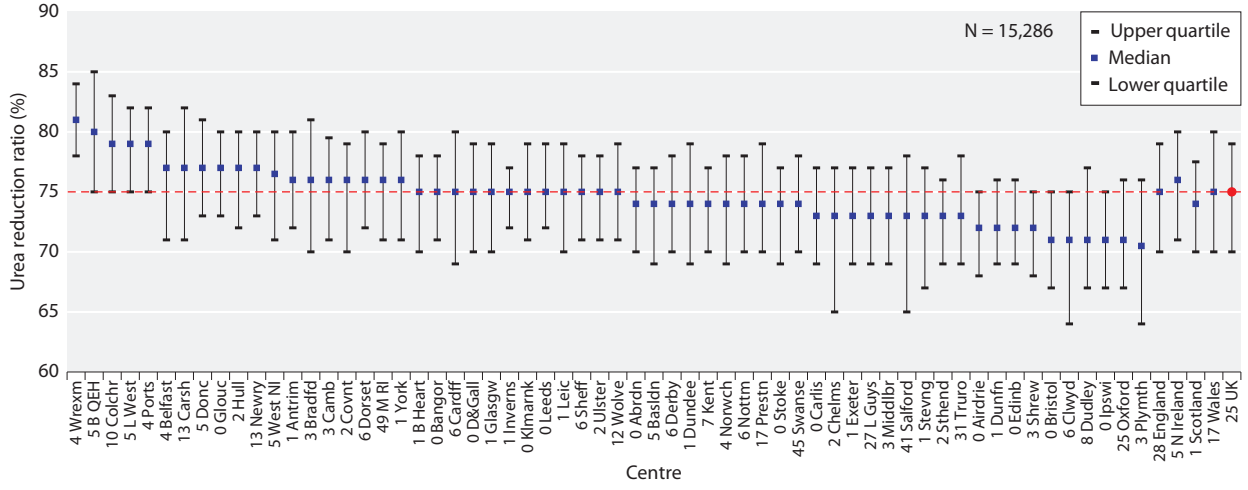

Fig. 9.1a. Median URR achieved in prevalent patients on HD by centre, 30/9/2012

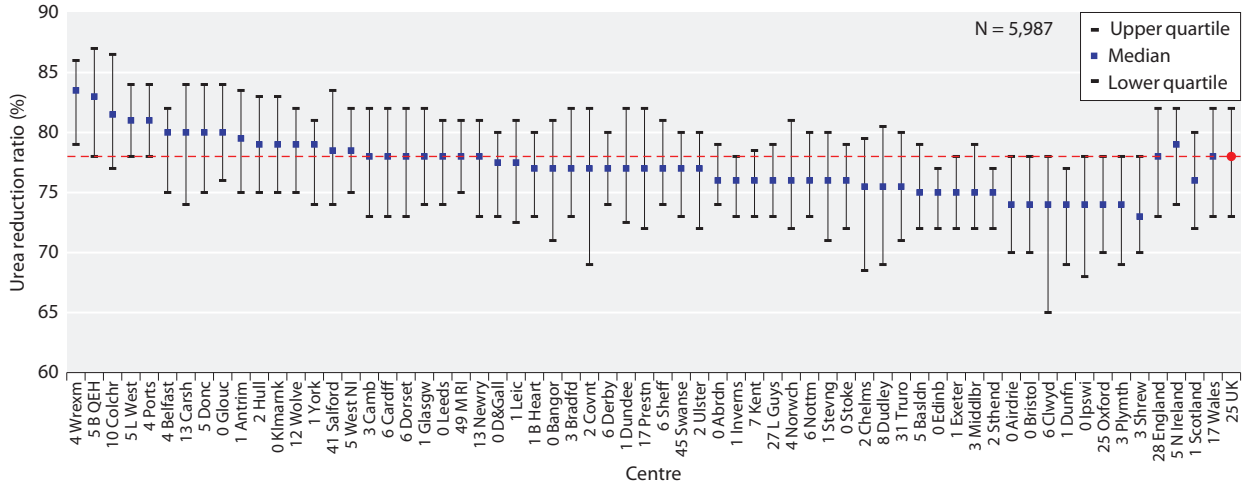

Fig. 9.1b. Median URR achieved in female prevalent patients on HD by centre, 30/9/2012

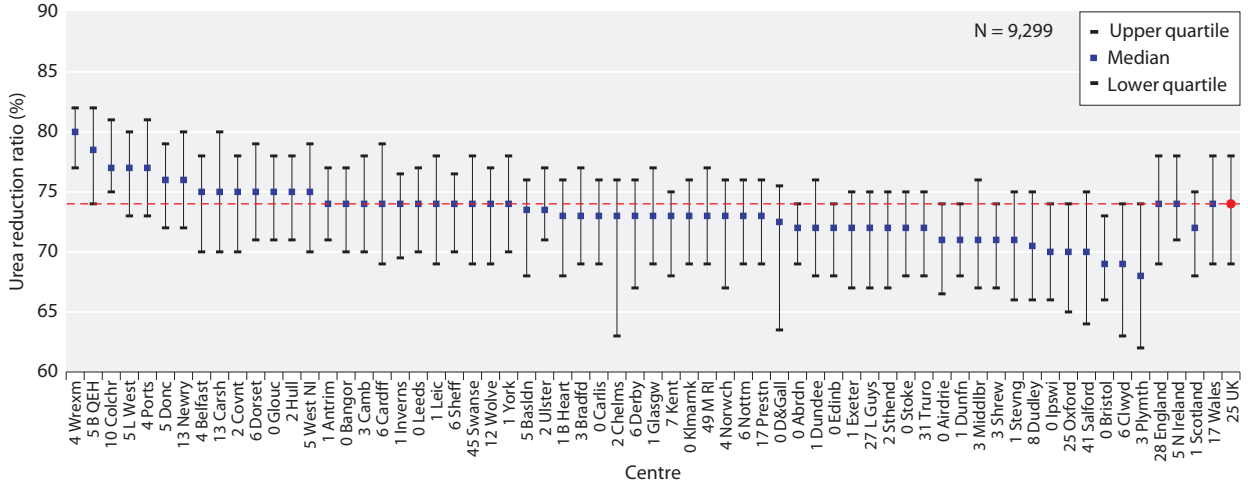

Fig. 9.1c. Median URR achieved in male prevalent patients on HD by centre, 30/9/2012

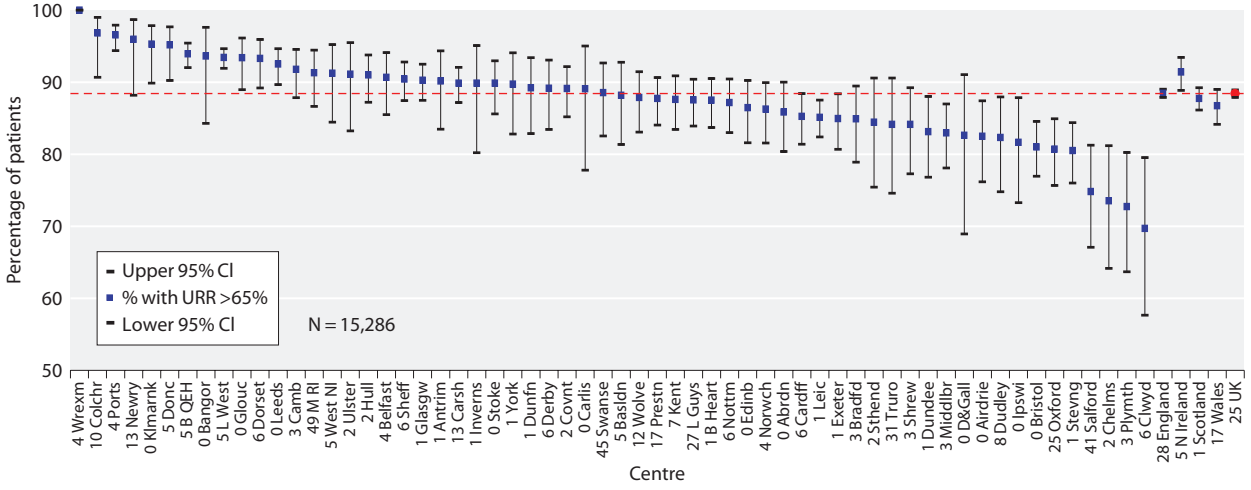

Fig. 9.2. Percentage of prevalent patients with URR >65% on HD by centre, 30/9/2012

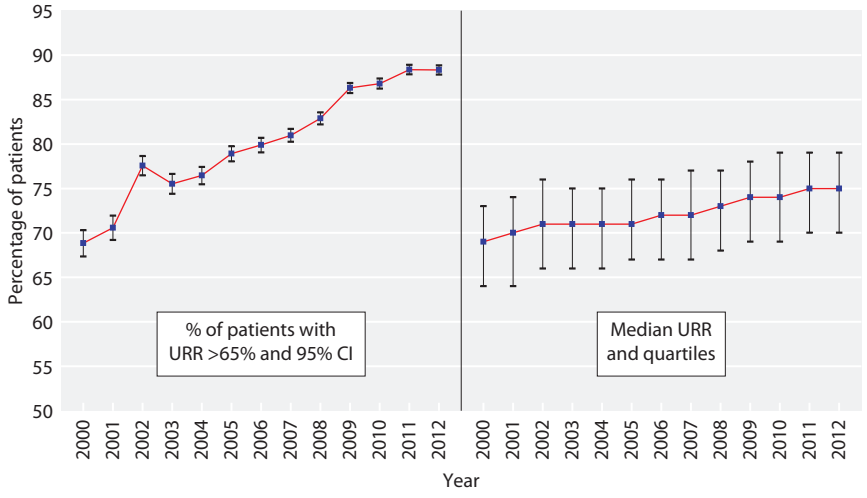

Fig. 9.3. Change in the percentage of prevalent patients on HD with URR >65% and the median URR between 2000 and 2012 in the UK

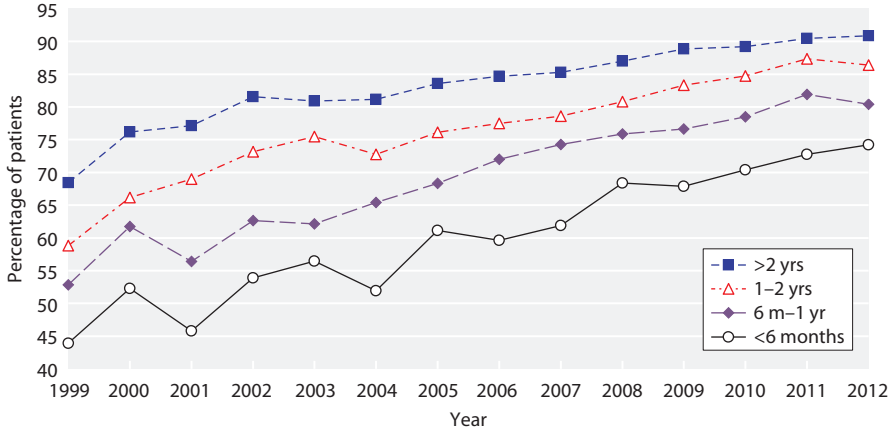

Fig. 9.4. Percentage of prevalent patients on HD achieving URR >65% by time on RRT between 1999 and 2012

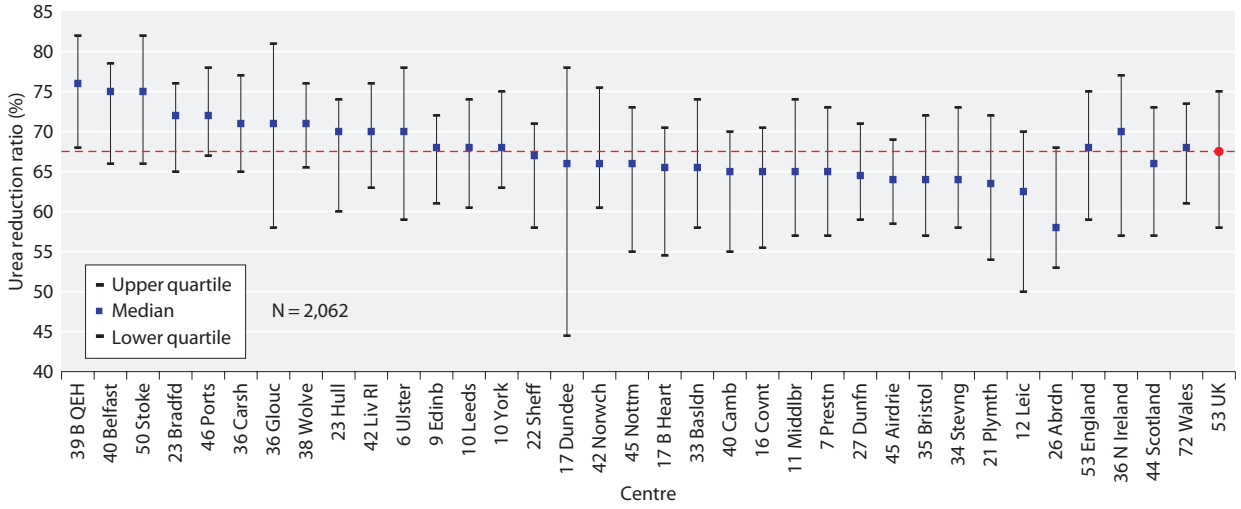

Fig. 9.5a. Median URR in the first quarter of starting RRT in incident patients who started haemodialysis in 2011

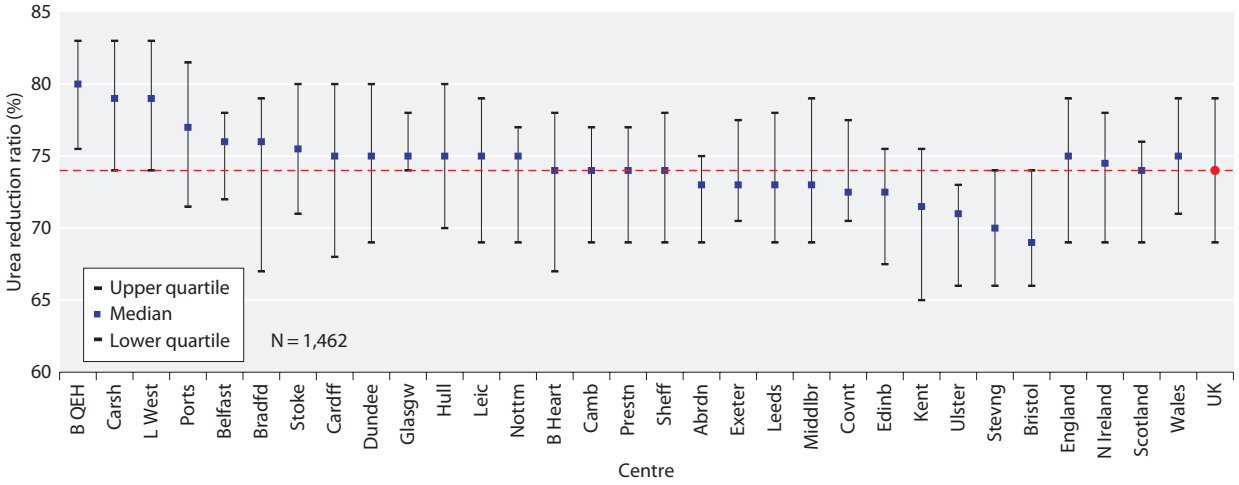

Fig. 9.5b. Median URR one year after starting RRT for patients who started haemodialysis in 2011

men in this analysis. This may simply reflect differences in dietary intake and lower pre-dialysis serum urea values in women, and as such does not necessarily imply improved urea clearances for women [14, 15].

In the prevalent haemodialysis population there was a wide range (69.7–100%) of achievement of the RA guideline for URR between different centres which is likely to reflect genuine differences in HD dose with both individual and centre level contributors. Understanding more fully individual renal centre practice would be informative. In the incident population, the variation in the between centre median URR within the first quarter for incident patients may represent variation in dialysis prescription practice for patients starting RRT. Some renal centres may use dialysis initially as a 'top-up' in individuals with residual renal function, whilst other centres use a more standardised 'full-dose' approach to dialysis prescription, irrespective of residual function. Although evidence supports that preservation of residual renal function is associated with improved survival [16], how much individualisation of dialysis prescription based on residual renal function is practiced across UK renal centres and how this correlates with outcomes is not currently known. Similarly, it is not known whether the decline in residual renal function is affected by differences in centre practice approach to initiating dialysis. Varied completeness of data returns across other important factors such as dialysis session also limits the interpretation of the data, and increases the risk of misclassification of patients in the presented analyses. For example, some patients who were receiving more or less frequent dialysis sessions than three times per week may be incorrectly categorised and introduce bias into the median estimate of URR and the percentage achieving the URR RA standard. Although RA guidelines recommend standardised methods for urea sampling, inconsistency in sampling methodology for the post-dialysis urea sample may also play a part in the variations seen [9].

Debate continues as to the toxicity of urea, and how representative urea clearance is of other azotaemic toxin clearances. In addition, the dialysis prescription should also be designed to achieve volume, sodium and divalent cation balance and correct metabolic acidosis. As such basing HD dosing simply on urea clearance is criticised by some [13] arguing that patient outcomes are improved by longer treatment times independent of urea removal [5, 17–22] and that clearance of 'middle molecules' has an important impact [23, 24]. However, no consensus has yet emerged on alternative markers of HD adequacy. The UKRR has historically reported URR, predominantly for logistical reasons with the URR being the easiest measure to calculate, and the measure of dialysis adequacy that is most complete when returned to the UKRR. However, the limitations of the URR are recognised. Although URR correlates well with single pool Kt/V (spKt/V) in population studies, significant variability in correlation in individual patients occurs because URR fails to include both the contraction in extracellular volume (ECV) and the urea generation during routine HD [11]. Neither URR nor spKt/V take into account post-dialysis urea rebound, potentially resulting in an over-estimate of the amount of dialysis actually delivered. A possible move to reporting eKt/V to the UKRR in addition to high quality data on

residual renal function, weights and dialysis prescription practice including duration and frequency of sessions would enhance the quality of analyses the UKRR could provide for the renal community, and would potentially allow for evaluation of different approaches to the initiation of dialysis and the effect of residual renal function.

Conflicts of interest: none

References

1 Gotch FA, Sargent JA: A mechanistic analysis of the National Cooperative Dialysis Study (NCDS). Kidney Int 1985;28:526–534
2 Owen WF, Lew NL, Liu Y, Lowrie EG, Lazarus JM: The Urea Reduction Ratio and Serum Albumin Concentration as Predictors of Mortality in Patients Undergoing Hemodialysis. N Engl J Med 1993;329:1001–1006
3 Held PJ, Port FK, Wolfe RA, Stannard DC, Carroll CE, Daugirdas JT, Bloembergen WE, Greer JW, Hakim RM: The dose of hemodialysis and patient mortality. Kidney Int 1996;50:550–556
4 Tentori F, Hunt WC, Rohrscheib M, Zhu M, Stidley CA, Servilla K, Miskulin D, Meyer KB, Bedrick EJ, Johnson HK, Zager PG: Which Targets in Clinical Practice Guidelines Are Associated with Improved Survival in a Large Dialysis Organization? J Am Soc Nephrol 2007;18: 2377–2384
5 Locatelli F, Buoncristiani U, Canaud B, Kohler H, Petitclerc T, Zucchelli P: Dialysis dose and frequency. Nephrol Dial Transplant 2005;20: 285–296
6 Depner TA: Assessing adequacy of hemodialysis: urea modeling. Kidney Int 1994;45:1522–1535
7 Movilli E: Simplified approaches to calculate Kt/V. It's time for agreement. Nephrol Dial Transplant 1996;11:24–27
8 Vanbelleghem H, Vanholder R, Levin NW, Becker G, Craig JC, Ito S, Lau J, Locatelli F, Zoccali C, Solez K, Hales M, Lameire N, Eknoyan G: The Kidney Disease: Improving Global Outcomes website: Comparison of guidelines as a tool for harmonization. Kidney Int 2007;71:1054–1061
9 UK Renal Association Clinical Practice Guidelines Committee. Haemodialysis, 2009 http://www.renal.org/Clinical/GuidelinesSection/Haemodialysis.aspx
10 European Best Practice Guidelines Expert Group on Haemodialysis. Nephrol Dial Transplant 2002:17(suppl 7):S16–S31
11 NKF-KDOQI clinical practice guidelines; update 2006. Am J Kidney Dis 2006:48(suppl 1):S2–S90
12 Depner T, Daugirdas J, Greene T, Allon M, Beck G, Chumlea C, Delmez J, Gotch F, Kusek J, Levin N, Macon E, Milford E, Owen W, Star R, Toto R, Eknoyan G, Hemodialysis Study Group Dialysis dose and the effect of gender and body size on outcome in the HEMO Study. Kidney Int. 2004;65(4):1386
13 Port FK, Wolfe RA, Hulbert-Shearon TE, McCullough KP, Ashby VB, Held PJ. High dialysis dose is associated with lower mortality among women but not among men. Am J Kidney Dis. 2004;43(6):1014
14 Lowrie EG: The Kinetic Behaviors of Urea and Other Marker Molecules During Hemodialysis. Am J Kidney Dis 2007;50:181–183
15 Spalding EM, Chandna SM, Davenport A, Farrington K. Kt/V underestimates the haemodialysis dose in women and small men. Kidney Int 2008;74:348–355
16 Hanson JA, Hulbert-Shearon TE, Ojo AO, et al.: Prescription of twice-weekly hemodialysis in the USA. Am J Nephrol 1999;19:625–633
17 Vanholder R, Eloot S, Van Biesen W: Do we need new indicators of dialysis adequacy based on middle-molecule removal? Nature Clinical Practice Nephrology 2008;4:174–175
18 Tattersall J, Martin-Malo A, Pedrini L, Basci A, Canaud B, Fouque D, Haage P, Konner K, Kooman J, Pizzarelli F, Tordoir J, Vennegoor M, Wanner C, ter Wee P, Vanholder R: EBPG guideline on dialysis strategies. Nephrol Dial Transplant 2007;22:ii5–21
19 Saran R, Bragg-Gresham JL, Levin NW, Twardowski ZJ, Wizemann V, Saito A, Kimata N, Gillespie BW, Combe C, Bommer J, Akiba T, Mapes DL, Young EW, Port FK: Longer treatment time and slower ultrafiltration in hemodialysis: Associations with reduced mortality in the DOPPS. Kidney Int 2006;69:1222–1228
20 Marshall MR, Byrne BG, Kerr PG, McDonald SP: Associations of hemodialysis dose and session length with mortality risk in Australian and New Zealand patients. Kidney Int 2006;69:1229–1236
21 Eloot S, Van Biesen W, Dhondt A, Van de Wynkele H, Glorieux G, Verdonck P, Vanholder R: Impact of hemodialysis duration on the removal of uremic retention solutes. Kidney Int 2007;73:765–770
22 Basile C, Lomonte C: Dialysis time is the crucial factor in the adequacy of hemodialysis. Kidney Int 2008;74:965–966
23 Eloot S, Torremans A, De Smet R, Marescau B, De Deyn PP, Verdonck P, Vanholder R: Complex Compartmental Behavior of Small Water-Soluble Uremic Retention Solutes: Evaluation by Direct Measurements in Plasma and Erythrocytes. Am J Kidney Dis 2007;50:279–288
24 Davenport A. How best to improve survival in haemodialysis patients: solute clearance or volume control? Kidney Int. 2011;80(10):1018–20