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CLINICAL STUDY

Trends in the use of renal replacement therapy modality in intensive care unit: a 7 year study*

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Abstract

Background: The use of renal replacement therapy (RRT) modality in the intensive care unit (ICU) depends primarily on provider preference and hospital resource. This study aims to describe the prevalence of RRT use and the trends in RRT modality use in the ICU over the past 7 years. **Methods:** All ICU admissions, including medical, cardiac, and surgical ICUs from 1 January 2007 to 31 December 2013, were included in this study. RRT use was defined as the use of intermittent hemodialysis (IHD) or continuous renal replacement therapy (CRRT) within a given ICU day. The RRT use was reported as the proportion of ICU days on each RRT modality divided by the total ICU days with RRT usage. **Results:** Over the course of this study (72,005 ICU admissions), 272,271 ICU days were generated. RRTs were used in 4110 ICU admissions (5.7%) and on 21,159 ICU days (7.8%). RRT use was 10,402 (49%) for IHD, and 10,954 (52%) for CRRT. The trend of IHD and CRRT use did not change from year 2007 to 2013. On ICU days with RRT, the choice of RRT modality was associated with the number of vasopressor use ($p < 0.001$). CRRT was more preferred on the ICU days with the increasing number of vasopressor use. **Conclusions:** RRTs were used in about 6% of ICU admission. The use of IHD and CRRT was similar and did not change over 7 years. The choice of RRT modality mainly depended on the number of vasopressors used on ICU days with RRT.

Keywords

Continuous renal replacement therapy/dialysis, Intensive care unit, intermittent hemodialysis, renal replacement therapy

History

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Background

Acute kidney injury (AKI) is very common in critically ill patients, occurring in patients admitted to intensive care units (ICUs) ranges from 30% to 60%.^{1–4} The management of patients with AKI is principally supportive, and renal replacement therapy (RRT) is indicated in patients with severe AKI.⁵

In 1977, continuous renal replacement therapy (CRRT) was used for the treatment of multi-organ failures due to inadequacies of conventional intermittent hemodialysis (IHD).^{6–8} For the past decades, many studies have demonstrated a number of physiological advantages of CRRT over conventional IHD, including hemodynamic stability, correction of hypervolemia, better solute removal.^{9–11} However, the physiologic superiority has not been translated into clinically superiority. In 2007, a systematic review and meta-analysis of randomized controlled trials (RCTs) of 15 studies with 1550 patients showed that the RRT modality, IHD versus CRRT, did not affect important patient outcomes.¹² Kidney Disease: Improving Global Outcomes (KDIGO) has subsequently recommended no preference of modality of RRT, but

emphasized the importance of adequacy of RRT, which were the delivering a dialysis efficiency (Kt/V) of 3.9 per week when using IHD and an effluent volume of 20–25 mL/kg/h for CRRT.¹³ As a result, the choice of RRT modality use primarily depends on physician preference and hospital resource. However, the data on the prevalence and the temporal trend of RRT use for the management of severe AKI for the past decade have not been carefully established.

Thus, we conducted this study to describe the temporal changes in the utilization of RRT modality in the ICU setting over the course of 7 years.

Methods

Study population and setting

This is a descriptive study investigating the use of various RRT modalities in the ICU setting at a tertiary referral hospital system. All adult ICU admissions (age 18 years or older) from 1 January 2007 to 31 December 2013 were examined at two Mayo Clinic hospitals in Rochester, MN. Patients without authorization were excluded. The Mayo Clinic Institutional Board Review approved this study.

The Mayo Clinic Rochester hospital system consists of the Rochester Methodist (342 inpatient beds) and Saint Marys (946 inpatient beds) campuses. Because of the geographic distance between Mayo Clinic and the nearest non-Mayo

**Institution:* This work was performed at Mayo Clinic in Rochester, MN.
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Clinic ICU, critical care services around Rochester are provided exclusively to the local population by the Mayo Clinic Rochester hospital system. This system consists of a total of 167 beds (2012 and 2013) with varying types and adult ICU capacities (Supplemental Table 1 available online at [http://informahealthcare.com/doi/suppl/\[doinumber\]](http://informahealthcare.com/doi/suppl/[doinumber])). Critical care specialists with internal medicine, anesthesiology, and/or surgery background manage and co-manage patients in all ICUs.

Data collection

Clinical characteristics and the use of vasopressors were collected using automated retrieval from the institutional electronic medical record system. End-stage renal disease was identified based on the International Classification of Disease (ICD-9) code of 585.5, 585.6, 996.73, 996.68, 996.56, 792.5 and 458.21. The use of RRT within a given ICU day (12:00 am to 11:59 pm) during an ICU stay was reviewed. RRT use was defined as the use of IHD or CRRT including continuous veno-venous hemofiltration (CVVH), continuous venovenous hemodialysis, continuous venovenous hemodiafiltration, and

slow continuous ultrafiltration, regardless of duration. The number of ICU days on any RRT and the number of ICU days on each RRT modality were collected. The use of each RRT modality was reported using the following formula:

$$P(\text{RRT modality}) = \frac{\text{The total number of ICU days on a given RRT modality}}{\text{The total number of ICU days on any RRT}}$$

To investigate the association between the choice of RRT modality and the number of vasopressors used, the use of vasopressor within ICU days with RRT was reviewed. Vasopressor was defined as the continuous intravenous administration of epinephrine, norepinephrine, phenylephrine, dopamine, or vasopressin, regardless of duration and dosage.

An electronic data extraction algorithm was developed to search for the use of dialyses and vasopressors within a given ICU day using data from a custom relational research database, which contains a near real-time copy of clinical data from the electronic medical record.¹⁴ This database stores pertinent fluid input/output and Medication Administration Record data within an average of 15 min from entry into the medical record and serves as the data repository for data rules development.¹⁴

To validate the accuracy of the electronic data extraction algorithm, 300 ICU patients were randomly select and comprehensive medical record review was performed for the use of RRT and vasopressors within a given ICU day. For RRT use, the algorithm has 100% sensitivity and 100% specificity (Table S2a available online at [http://informahealthcare.com/doi/suppl/\[doinumber\]](http://informahealthcare.com/doi/suppl/[doinumber])). For vasopressor use, the algorithm has 97% sensitivity and 100% specificity (Table S1b available online at [http://informahealthcare.com/doi/suppl/\[doinumber\]](http://informahealthcare.com/doi/suppl/[doinumber])).

Statistical analysis

Continuous variables were reported as mean \pm standard deviation (SD) for normally distributed data and median with interquartile range (IQR) for skewed data. Categorical variables were reported as counts and percentages. We calculated the proportion of ICU days on each RRT modality divided by the total ICU days with RRT usage: P (IHD), P (CRRT). The trend in the use of each RRT modality in each year from 2007 to 2013 was graphically represented and

Table 1. Clinical characteristics.

Variable	Total ($n = 72,005$)
Age, year (SD)	63 \pm 17
Male sex (%)	41,633 (58)
White (%)	66,007 (92)
BMI (SD)	29.8 \pm 8.0
End-stage renal disease (%)	4480 (6)
ICU admission type ^a (%)	
Cardiac SICU	15,631 (22)
CCU	8807 (12)
MICU	16,863 (23)
SICU	19,997 (28)
Mixed ICU	10,707 (15)
Admission SOFA score ^b (IQR)	4 (2–7)
Admission APACHE III score (SD)	67 \pm 26
MV use in ICU (%)	28,844 (40)
ICU length of stay, day (IQR) ^b	2 (2–4)
ICU mortality (%)	2755 (4)
In-hospital mortality (%)	4896 (7)

Notes: Continuous variable are reported as mean \pm SD; categorical variables are reported as count (%) if not indicate.

^aThe first ICU admission unit in case of ICU transfer.

^bData are shown as median (IQR).

Table 2. Proportion of ICU with dialysis use divided by total ICU admission and proportion of total ICU day on dialysis over total ICU day.

ICU	Total ICU	Total ICU with dialysis	%ICU with dialysis	Total ICU day	Total ICU day on dialysis	%ICU day on dialysis
All	72,005	4110	5.7	272,271	21,159	7.8
Admission year						
2007	10,070	619	6.1	40,121	3547	8.8
2008	10,373	564	5.4	39,956	2818	7.1
2009	10,006	544	5.4	37,815	2669	7.1
2010	10,265	576	5.6	38,390	2833	7.4
2011	10,682	666	6.2	41,601	3491	8.4
2012	10,473	603	5.8	38,187	2955	7.7
2013	10,136	538	5.3	36,201	2846	7.9

Notes: %ICU with dialysis use = total ICU with dialysis use/total ICU. %ICU day on dialysis = total ICU day on dialysis/ICU day.

visually inspected. The association between the choice of RRT modality and the number of vasopressors used on ICU days with RRT was assessed using the chi-squared test. All analyses were performed using JMP statistical software (version 10, SAS, Cary, NC).

Results

From 2007 to 2013, there were 72,005 ICU admissions and 272,271 ICU days. The clinical characteristics, ICU and

Table 3. The proportion of specific dialysis modality use in ICUs from 2007 to 2013.

Vasopressor	All	ICU admission year						
		2007	2008	2009	2010	2011	2012	2013
<i>P</i> (IHD)	0.49	0.47	0.49	0.49	0.53	0.50	0.50	0.47
<i>P</i> (CRRT)	0.52	0.54	0.51	0.52	0.49	0.51	0.51	0.54

Notes: *P* (IHD) = total ICU day IHD/total ICU day on dialysis. *P* (CRRT) = total ICU day on continuous renal replacement therapy/ total ICU day on dialysis.

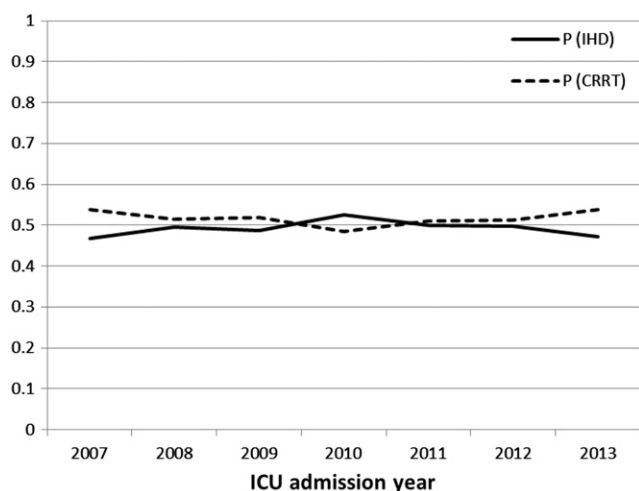


Figure 1. Trend of specific dialysis modality use in all ICUs from 2007 to 2013.

hospital outcomes are summarized in Table 1. The mean age was 63 ± 17 years. Fifty-eight percent were male and 6% had end-stage renal disease before ICU admission. The median SOFA score was 4 (IQR 2–7). The median ICU length of stay was 2 (IQR 2–4) days. Four percent and 7% died in ICU and hospital, respectively.

RRTs were used in 4110 of ICU admissions (5.7%) and on 21,159 ICU days (7.8%). The ICU and in-hospital mortality were 16% and 24%, respectively. The use of RRT ranged from 5.3% to 6.2% of ICU admission and 7.1% to 8.8% of ICU days over 7 years (Table 2). Out of 21,159 ICU days with RRT use, IHD was used for 10,402 (49%) and CRRT for 10,954 (52%). The trend of IHD and CRRT use did not substantially change from 2007 to 2013 (Table 3 and Figure 1). Among non-ESRD patients, out of 12,359 ICU days with RRT use, IHD was used for 4370 (35%) and CRRT for 8124 (66%). In contrast, among ESRD patient, out of 8800 ICU days with RRT use, IHD was used for 6032 (69%) and CRRT for 2830 (32%).

Of ICU days with RRT use, 51% were on vasopressor. The choice of RRT modality was significantly associated with the use and number of vasopressor use ($p < 0.001$ both). Of ICU days with RRT but without vasopressor use, IHD was used on 70% versus CRRT on 30%. In contrast, of ICU days with RRT and vasopressor use, IHD was used on 27% versus CRRT on 72% (Table 4a). CRRT was increasingly preferred on the ICU days with the increasing number of vasopressor use (Table 4b).

Discussion

RRTs were used in about one-twentieth of ICU admission. The use of IHD and CRRT was comparable and did not change over 7 years of our study. Overall, the choice of RRT modality was correlated with the number of vasopressors used on ICU days with RRT, when CRRT was more preferred on the ICU days with the increasing number of vasopressor use.

Despite the releases of the systematic review and meta-analysis in 2007¹² and KDIGO clinical practice guideline for AKI in 2012 showing no superiority of clinical outcomes of CRRT over IHD, the trends in the use of RRT modality, IHD and CRRT, had not been changed between 2007 and 2013.

Table 4. The correlation between the choice of dialysis modality and vasopressor use on ICU days with dialysis.

	Dialysis modality used			
	IHD	Both	CRRT	Total
<i>(a) The use of vasopressor</i>				
Vasopressor use				
No	7292 (69.6)	64 (0.6)	3116 (29.8)	10,472
Yes	2913 (27.3)	133 (1.2)	7641 (71.5)	10,687
Total	10,205 (48)	197 (0.9)	10,757 (50.8)	21,159
<i>(b) The number of vasopressor use</i>				
Number of vasopressor				
0	7292 (69.6)	64 (0.6)	3116 (29.8)	10,472
1	2077 (36.5)	59 (1.0)	3552 (62.5)	5688
2	704 (18.9)	49 (1.3)	2981 (79.8)	3734
3	124 (10.8)	20 (1.7)	1009 (87.5)	1153
4	7 (7.4)	5 (5.3)	83 (87.4)	95
5	1 (5.9)	0 (0)	16 (94.1)	17
Total	10,205 (48)	197 (0.9)	10,757 (50.8)	21,159

$p < 0.001$.

This was likely due to the evidence of physiological benefits of CRRT.^{9–11} Interestingly, even the meta-analysis revealed no differences in hemodynamic stability and hypotensive events between the two modalities, IHD and CRRT, intensivists and critical care nephrologists preferred CRRT to IHD correlated with higher vasopressor uses as demonstrated in our current study. This finding reflected that many clinicians had still believed in the CRRT's physiological advantages when patients encountered severe AKI with hemodynamic instability requiring vasopressor agents despite the higher costs of providing CRRT than IHD.¹⁵ In addition, for patients who are at risk of or who have increased intracranial pressure including neurosurgical patients, patients with encephalitis or acute liver failure, studies have demonstrated the benefits of prevention of the surge in intracranial pressure.^{16–18}

The future trend of the use of RRT modality in ICUs may change as a number of results of recent published studies favoring CRRT on the clinical outcomes. In 2014, Wald et al.¹⁹ reported the findings of their retrospective cohort study conducted between July 1996 and December 2009. Compared with IHD, the investigators found that initiation of CRRT was associated with a 0.75-fold lower likelihood of chronic dialysis. Although there is currently no definite evidence from RCTs showing superiority of CRRT on clinical outcomes,^{20,21} this has been suggested likely because of the lack of sufficiently powered, multicenter RCTs.⁶

This study has several limitations. First, this is a single-center, retrospective study in the USA. This limits the generalizability of some results, especially to other countries. For example, in the Australian ICU, the use of conventional IHD has been discouraged since 2001.²² Second, we did not investigate the trend of each type of CRRT since CVVH has been used in our institution for the majority of cases with severe AKI (greater than 95%). Lastly, due to the descriptive nature of this study, the results are only reflective of the preference of RRT use; not appropriate use or patient outcomes. Thus, a multi-center, prospective study is ultimately required to address these limitations.

In summary, RRTs were used in about one-twentieth of ICU admission. The uses of the two modalities, IHD and CRRT, were similar and had not changed over 7 years. The choice of RRT modality mainly depended on the number of vasopressors used on ICU days with RRT, when CRRT was more preferred on the ICU days with the increasing number of vasopressor use.

Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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