Ventricular Arrhythmia Burden and Relationship to Interdialytic Period in Dialysis Patients with Cardiac Devices

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Abstract

Background: Sudden cardiac death (SCD) is a major driver of mortality in patients with end-stage renal disease (ESRD) on hemodialysis (HD). The degree to which ventricular arrhythmias (VA) play a role in SCD in ESRD patients is unclear. Objective: Use cardiac implantable electronic devices (CIEDs) to clarify VA burden in ESRD patients overall and in relation to interdialytic cycle. Methods: We identified 44 patients at a single academic center with CIEDs, 22 on HD, along with 22 age- and sex-matched controls. Device interrogations from 11/13/14 – 4/8/19 were reviewed. Results: Overall, there were no differences in HD patients and controls in adjusted overall event rate (HD 9.81 x 10-5 ± 1.5 x 10-3 events/patient-hours vs control 3.71 x 10-5 ± 9.1 x 10-4 events/patient-hours, p = 0.902), or proportion of patients experiencing VA event (HD 45.4% vs control 63.6%, p = 0.226). There was no difference in ventricular pacing burden. Controls were more likely to require device therapy for VT/VF episodes (total ATP episodes 2/38 in HD vs 10/22 in controls, p < 0.01, total ICD shocks 10/38 in HD vs 17/22 in controls, p < 0.01). HD patients were most likely to experience VA within 12-hours of HD completion (p < 0.01), and the vast majority of events were NSVT. Conclusion: VA and ventricular pacing burden was similar by CIED analysis between groups. In HD patients, VA were likely to occur within the first 12 hours post-dialysis, were primarily NSVT, and were unlikely to require device therapy.

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ABSTRACT

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Objective: Use cardiac implantable electronic devices (CIEDs) to clarify VA burden in ESRD patients overall and in relation to interdialytic cycle.

Methods: We identified 44 patients at a single academic center with CIEDs, 22 on HD, along with 22 age- and sex-matched controls. Device interrogations from 11/13/14 – 4/8/19 were reviewed.

Results: Overall, there were no differences in HD patients and controls in adjusted overall event rate (HD $9.81 \times 10^{-5} \pm 1.5 \times 10^{-3}$events/patient-hours vs control $3.71 \times 10^{-5} \pm 9.1 \times 10^{-4}$ events/patient-hours, $p = 0.902$), or proportion of patients experiencing VA event (HD 45.4% vs control 63.6%, $p = 0.226$). There was no difference in ventricular pacing burden. Controls were more likely to require device therapy for VT/VF episodes (total ATP episodes 2/38 in HD vs 10/22 in controls, $p < 0.01$, total ICD shocks 10/38 in HD vs 17/22 in controls, $p < 0.01$). HD patients were most likely to experience VA within 12-hours of HD completion ($p < 0.01$), and the vast majority of events were NSVT.

Conclusion: VA and ventricular pacing burden was similar by CIED analysis between groups. In HD patients, VA were likely to occur within the first 12 hours post-dialysis, were primarily NSVT, and were unlikely to require device therapy.

Key words: Ventricular arrhythmia, CIED, end-stage renal disease, hemodialysis

CONDENSED ABSTRACT

Sudden cardiac death (SCD) is the primary driver of mortality in patients with end-stage renal disease (ESRD). Historically, SCD has been assumed to be due to fatal ventricular arrhythmias (VAs), but recent data has suggested bradyarrhythmias and asystole may actually play a larger role than previously suspected. We compared cardiac implantable electronic device (CIED) interrogation data in ESRD and non-ESRD patients and found no differences in VA burden between groups. Additionally, control patients were more likely to require device therapies. Thus, VA events may play a smaller role in SCD in ESRD patients than previously assumed.

ABBREVATIONS LIST

SCD: Sudden cardiac death

ESRD: End-stage renal disease

HD: Hemodialysis

PD: Peritoneal dialysis

CIED: Cardiac implantable electronic devices

VA: Ventricular arrhythmia

LIDP: Long-interdialytic period

ATP: Anti-tachycardia pacing

NSVT: Non-sustained ventricular tachycardia

VT: Ventricular tachycardia

VF: Ventricular fibrillation

WCD: Wearable cardioverter-defibrillator

ILR: Implantable loop recorder

INTRODUCTION

Sudden cardiac death (SCD) is the most common cause of death in patients with end-stage renal disease (ESRD) on hemodialysis (HD) [1]. Two-thirds of these sudden deaths are due to fatal arrhythmias, accounting for 26% of overall mortality [2-5]. Historically, ventricular arrhythmias (VA) have been thought to be the primary driver of SCD in this population. However, emerging data suggest that bradyarrhythmias and asystole, rather than VA, may be the major cause of arrhythmia-related death in ESRD patients [6-7]. Beyond arrhythmia etiology itself, temporal relationships have been demonstrated between arrhythmia burden, SCD, and HD schedule, such that the long-interdialytic period (72-hours, LIDP) has been associated with higher rates of arrhythmic events, as well as increased hospitalization rates and mortality [6-11]. Thus, there is a crucial need for clarification of both tachy- and bradyarrhythmia etiology, prevalence, and contribution to mortality in ESRD patients on HD, while also defining the temporal relationships between interdialytic period duration and arrhythmia risk. Cardiac implantable electronic devices (CIEDs) offer a unique and underutilized source of rhythm data analysis which might be used to investigate the differences in arrhythmia risk and timing between ESRD patients on HD and controls. To our knowledge, this is the first study systematically evaluating the arrhythmia burden in ESRD patients with CIEDs compared to control patients with CIEDs.

METHODS

Study population

We retrospectively reviewed 921 patients included on the active HD list at a single large academic center. Of these patients, we identified 22 patients with a CIED, and specific HD schedule for each patient was recorded. Patients were aged 25 to 82 years, and included both men and women. We also systematically selected 22 age- and sex-matched patients with a CIED not on HD to serve as controls. Patients on peritoneal dialysis (PD) were excluded. For all patients, we recorded demographic, comorbidity, medication, laboratory, and echocardiographic data by retrospective chart review. For HD patients, we also documented ESRD etiology and HD start date. This study was approved by the Institutional Committee on Human Research at the University of Virginia Health System.

Device interrogations

We reviewed all available device interrogations for the 44 patients included in this study, the dates of which ranged from 11/13/14 through 4/8/19. Devices included were single-chamber pacemakers, dual-chamber pacemakers, single-chamber ICDs, biventricular pacemakers and defibrillators, and subcutaneous ICDs. All interrogations, obtained both in the ambulatory and inpatient settings, were reviewed. For each CIED, the device type and implantation date were recorded. We calculated total number of transmissions and monitoring hours for all patients in the study. For VA analysis, the following were recorded: number of VT/VF events, number of non-sustained VT (NSVT) events, and ventricular pacing percentage. We defined VT as a wide-complex, regular tachycardia having a duration greater than thirty seconds and/or requiring either anti-tachycardia pacing (ATP) or ICD shock for termination. Thus, NSVT was defined as a wide-complex regular tachycardia lasting at least three beats but not meeting aforementioned VT criteria. For each NSVT, VT, and VF episode, the following details were recorded: date, time, day of week, duration, average atrial rate, average ventricular rate, and therapy requirement (i.e. ATP, ICD shock, or both).

In order to compare overall VA burden between groups, we calculated the total number of VA events divided by the product of the total number of patients per group experiencing any VA event and total number of monitoring hours for those patients. This resulted in events per patient-hour for both individual patients and for each group. We chose this calculation in order to account for the fact that patients monitored for longer periods of time may represent a survival bias.

In an attempt to better categorize ventricular pacing data, four quartiles for each group (0-25%, 26-50%, 51-75%, and 76-100%) were created and represented the pacing percentage reported since last device interrogation. Individual counts represented a device interrogation reporting a particular ventricular pacing percentage in the range of the specified quartile. Biventricular devices and subcutaneous ICDs were excluded from ventricular pacing analysis.

Dialysis flowsheet data and dialytic cycle

For patients on HD, intradialytic flowsheet data was reviewed for sessions occurring from the date of the patient's first device interrogation onward. Relationship between the dates of HD initiation and CIED implantation was also recorded. Intradialytic flowsheet data included the following: HD start time, HD end time, route of vascular access, pre- and post-dialysis blood pressure, and target weight. For patients initiated on HD after CIED implantation, VA events pre- and post-HD initiation were recorded. Additionally, the timing of VA events in relation to the most recent HD session was documented. Specifically, the number of events occurring during HD were recorded, as were the number of events occurring within each of the twelve-hour windows from the time of HD end through more than 72 hours after HD end.

Outcomes

The primary outcomes of interest included VA events, hospitalization, and all-cause mortality. For hospitalization and mortality outcomes, only events observed within the confines of the given patient's interrogation date range were counted. Secondary outcomes included ventricular pacing burden, required therapies for ventricular events (i.e. anti-tachycardia pacing and/or ICD shock), and stroke rates between the two groups. Similar to hospitalization and mortality, stroke rates within the defined interrogation dates for a given patient were counted.

Statistics

All demographic information between HD patients and controls was compared using Pearson's chi-square test. Comparisons between ventricular event rates, ventricular pacing data, and ventricular event rates with respect to dialysis schedule were also compared using chi-square tests. Fisher's exact test was use to compare average TSH and EF between the two groups, as well as to compare VT event rates between HD and controls given the rarity of the event. Statistical analyses were performed by SAS software (version 9.4, SAS Institute Inc., Cary, NC, USA).

RESULTS

Demographics

There were no baseline differences between HD patients and controls in age, sex, prevalence of atrial fibrillation/flutter, prevalence of heart failure (HF), cardiac medication regimen (beta-blocker, calcium channel blocker, antiarrhythmic drug, or digoxin use), device type, most recent EF, most recent thyroid function testing, or levothyroxine use. However, HD patients were more likely to have OSA (55% vs 9.1%, p = 0.001,**Table 1**). Additionally, the control group had a higher number of white patients compared to the HD group (HD 10/22 vs control 18/22, p = 0.01, **Table 1**). Of patients on HD, 12 (54.5%) were maintained on a Monday-Wednesday-Friday schedule, 9 (40.9%) on a Tuesday-Thursday-Saturday schedule, and one patient (4.5%) was maintained on a specialized home HD schedule (five HD sessions per week, three hours per session). The mean dialysis vintage was 3.36 ± 2.5 years. There were no differences in baseline characteristics between HD patients who did and did not suffer a VA event. Finally, there were no differences between HD

patients and controls in prevalence of device type. Among patients with ICDs, no differences existed between groups in device indication (i.e. equivalent rates of primary and secondary prevention ICDs, **Table 2**).

In total, HD patients experienced 206 events, while control patients experienced 164 (**Figure 1**). Of the 206 total events in the HD group, 168 were NSVT (81.6%), 2 were VT (0.97%), and 36 were VF (17.5%). Of the 164 total events in the control group, 142 were NSVT (86.6%), 1 was VT (0.6%), and 21 were VF (12.8%). There was no difference between groups in the proportion of patients experiencing any VA overall (HD 45.4% vs control 63.6%, p = 0.226). There were no differences between groups in the adjusted overall event rate (HD 9.81 x 10^{-5} ± 1.5 x 10^{-3}events/patient-hours vs control 3.71 x 10^{-5} ± 9.1 x 10^{-4} events/patient-hours, p = 0.902), NSVT adjusted event rate (8.00 x 10^{-5} ± 9.7 x 10^{-4}vs 3.58 x 10^{-5} ± 8.7 x 10^{-4}, p = 0.910), VT event rate (5.35 x 10^{-5} ± 0 vs 4.29 x 10^{-5} ± 0, p = N/A), or VF event rate (9.48 x 10^{-4} ± 8.1 x 10^{-4} vs 1.29 x 10^{-4} ± 8.4 x 10^{-5}, p = 0.154). There were no differences in device indication between groups (**Table 2**).

Though we found a similar rate of VA events in both groups, the control group had a higher incidence of VA requiring therapies. As stated, HD patients experienced a total of 38 VT/VF events, compared to 22 events in the control group. Despite experiencing fewer numbers of VT/VF events, control patients required significantly higher rates of device therapy in the form of both ATP episodes and ICD shocks (total ATP episodes 2/38 in HD vs 10/22 in controls, p = 0.0002, total ICD shocks 10/38 in HD vs 17/22 in controls, p = 0.0001, **Table 2**). The significance observed in these therapies was driven primarily by statistically-significant differences in VF episodes requiring device intervention (**Table 2**).

Ventricular pacing burden

In comparing ventricular pacing burden between groups, there was no difference in likelihood to require pacing greater than 50% of the time (HD 36/190 counts, control 41/185 counts, p = 0.441). By quartile, HD patients more frequently paced in the range of 26-50% of the time (HD 21/190 counts vs 1/185 counts, p < 0.001, **Figure 2**), but no other differences between groups by quartile were found.

Events temporal to HD session

Of the 22 HD patients, 10 (45.5%) experienced any VA, with only 6 patients (27.3%) experiencing any event after their date of HD initiation, for a total of 79 events. NSVT accounted for 77 events (97.5%), 0 were VT (0%), and 2 were VF (2.5%). Six events (7.6%) occurred during HD. For the remaining events, the average time from last HD session was 43 hours, but with a high degree of variability (SD = 159.4 hr). Events were most likely to occur within 12 hours of HD end (χ^2 = 19.7, dF = 7, p = 0.006, **Figure 3**), with the next most common intervals being 12-24 hours (22.8% of events) and 36-48 hrs (20.2% of events), though these intervals did not reach statistical significance (p = 0.09 and 0.19, respectively). One event required ATP, while only two events required ICD shock.

Outcomes

We found no difference in stroke (HD 2/22 vs control 1/22, p = 0.55) or mortality (HD 1/22, control 2/22, p = 0.55) between the groups. However, HD patients had a significantly shorter time to first hospitalization compared to controls (p = 0.04, **Figure 4**).

DISCUSSION

In this study, we sought to define and quantify the VA burden ascertained from CIED monitoring in ESRD patients on HD and age, sex-matched controls. Our key findings were 1) utilization of CIED monitoring in HD patients to define arrhythmia burden is feasible and easily accessible, 2) no significant differences existed between groups in VA prevalence, though control patients experiencing VA were more likely to require device therapy, and 3) in HD patients experiencing VA, events were most likely to occur within 12 hours of HD end, with the vast majority being NSVT.

Over 720,000 Americans are living with ESRD, and the vast majority of incident cases (87.3%) will pursue renal replacement therapy in the form of HD [1]. The high rate of mortality observed in this population has been an area of active interest, as ESRD patients on dialysis exhibit an annual mortality of 16% [1].

The average expected remaining lifespan of patients initiated on HD is six years, less than one-third that of their age-matched counterparts in the general population [1]. Non-white patients are at particular risk of ESRD development, with African-Americans and Native Americans 3.4 times and 1.6 times more likely, respectively, to progress to ESRD compared to white patients [1], a trend reflected in our cohort as well. Cardiovascular disease is the primary driver of mortality in patients on dialysis, with the specific etiologies of arrhythmia and cardiac arrest accounting for 40% of deaths overall [2-6]. Comparatively, patients with congestive heart failure (CHF) have a projected mortality approaching 50% over five years [12]. Over 70% of ESRD patients on HD have at least one cardiovascular comorbidity, which might be expected as they share several common risk factors [1].

Historically, the majority of fatal sudden cardiac death (SCD) events in patients on HD were assumed to be fatal VA. One study of 75 patients on HD with a wearable cardioverter defibrillator found that 79% of sudden cardiac arrhythmias (SCA) were attributable to VT or VF [13]. Additionally, unpublished emergency medical services data across nine ambulatory hemodialysis centers found that 62% of cardiac arrests were attributable to VT or VF [5]. In our cohort, we found that 10 HD patients (45%) experienced any VA, with a substantial portion of total ventricular events (18.4%) representing VT or VF.

However, our study also demonstrated that the VA burden between ESRD patients on HD and controls was similar. Though nearly half of HD patients (45.4%) experienced VA events, the vast majority of events were NSVT (81.6%), and there were no differences in VA subtype between the two groups. Despite similar rates of VT and VF, HD patients were less likely than controls to require CIED therapy in the form of ATP or ICD shock. The fact that the vast majority of events experienced by HD patients were NSVT, and that control patients were more likely to actually require device therapy for ventricular events, might suggest that ventricular ectopy in the HD population may not be clinically-actionable.

Similar observations have been described elsewhere. For example, in one study of HD patients prescribed a wearable cardioverter defibrillator (WCD), the type of SCA experienced seemed to predict future survival. Specifically, though 79% of total SCAs were VT/VF (compared to 21% of events being asystole), 91% of patients with VT/VF were alive within 24 hours of their SCA event, and over half were alive at thirty days. By comparison, only one patient with asystole survived more than three days post-SCA [13]. Thus, though VT/VF events may have been more common, asystole events were more likely to be fatal.

The notion that VA events may not play a major role in the mortality of HD patients has also been supported by recent interventional studies. For example, the recently-published ICD2 trial, a prospective randomized study which implanted primary prevention ICDs in 188 ESRD patients on HD with LVEF [?]35%, found no difference in SCD between the ICD and non-ICD groups. In fact, the trial was ultimately stopped early due to futility of the intervention [14]. Similarly, data derived from over 700 in-center cardiac arrests across more than 500 ambulatory dialysis clinics found that survival after such events does not appear to be impacted by the presence or absence of an automated external defibrillator [15]. Taken together, these findings suggest that primary prevention against VA events may not significantly impact mortality in ESRD patients on HD.

In contrast, there is increasing evidence that bradyarrhythmias and asystole may be the major contributors to SCD in the HD population. In a study performed in the United Kingdom during which 30 patients on HD received an implantable loop recorder, bradyarrhythmias, rather than tachyarrhythmias, emerged as the commonest and most significant arrhythmic events, with 17% of participants meeting the combined primary outcome of either SCD or implantation of a pacing device [16]. More recently, outcomes data for the Monitoring in Dialysis (MiD) Study examined implantable loop recorder data in 66 patients over a six month period, and found that 87% of the clinically-significant arrhythmias detected were bradycardic events [6]. Of note, a high degree of cardiovascular comorbidity was observed in this particular cohort. These data raise the important question of whether implantable cardiac pacemakers, rather than ICDs, may impact survival in HD patients, especially given their demonstrated reduction in mortality among bradycardic non-HD patients [5, 17].

Ideally, we would have hoped to compare bradyarrhythmia events between HD patients and controls, but

were unable to do so given the compensatory pacing ability of CIEDs. Therefore, we chose to compare ventricular pacing burden between groups as a surrogate for bradyarrhythmia burden. However, comparing ventricular pacing burden between populations is challenging. Device interrogations report percent time since last device interrogation spent ventricular pacing. There exists a high degree of variability 1) in the number of interrogations between patients, 2) the amount of time between interrogations for a single patient, and 3) the absolute pacing percentage reported by the device. We therefore utilized a quartile method, and found that control patients were more likely to pace in the 26-50% quartile compared to HD patients. This finding does not appear to be clinically-significant. Overall, we interpret this data as demonstrating no significant increase in pacing burden in HD patients, which suggests no difference in clinically-relevant bradycardic episodes between dialysis patients and controls.

However, an important question generated by the similar pacing trends observed in our HD and control cohorts is whether bradyarrhythmias in HD patients reflect an end-stage myocardial failure (as suggested by prior studies), or true electrophysiological malfunction. For example, the longest pause duration among patients studied by Wong et al. [7] was 2 seconds, which generally would not be considered relevant in clinical practice. In the CRASH-ILR study [16], pauses ranged between 3 and 7 seconds. Trends in arrhythmia subtype prevalence may be a function of dialysis vintage, with VA more common following HD initiation and bradycardic events becoming more common after a long period of dialysis dependence. However, a large degree of variation in dialysis vintage exists both between and within studies, making relationships between dialysis vintage and documented pause and/or asystole duration difficult to interpret. For example, the mean HD vintage in our population was 3.36 ± 2.5 years, while those in the MiD study [5, 6], Wong et. al [7], and CRASH-ILR [16] were 2.4 years (no SD given), 6 ± 4 years, and 3.75 ± 3.3 years, respectively. Interestingly, the cohort with the longest mean dialysis vintage [7] also demonstrated the shortest maximal pause duration (2 seconds). Thus, additional research is needed to clarify the relationships between clinically-significant bradycardia in HD patients and how this might relate to dialysis vintage.

Finally, beyond the questions of arrhythmia type and potential impact of cardiac device interventions, there have also been interesting temporal relationships demonstrated between arrhythmia burden, SCD, and HD schedule. Both all-cause mortality and mortality due to cardiovascular disease peak in the second month following HD initiation, then downtrend [1]. Similarly, arrhythmia burden is not evenly distributed across intervals of the HD schedule. In ESRD patients on HD, three interdialytic periods exist: one long interdialytic period (LIDP, 72 hours) and two short interdialytic periods (SIDP, 48 hours each). The final hours of the LIDP as well as during the first weekly dialysis session itself have each been shown to be critical periods during which overall arrhythmia burden is greatest [6-11]. A recent study in the United Kingdom demonstrated that the LIDP is associated with higher rates of hospital admission, all-cause mortality, and out-of-hospital death rates [5, 11]. More specifically, bradycardic events appear to occur with significantly greater frequency toward the end of the inter-dialytic period compared to other intervals throughout the week [6].

In our cohort, we found that VA were most likely to occur within 12 hours of dialysis end. No other intervals reached statistical significance. These findings are inconsistent with available studies implicating the end of the LIDP as the most arrhythmogenic interval [8, 9]. This discrepancy in findings may be due in part to the fact that our cohort was maintained on variable dialytic schedules. However, our results do support previous studies suggesting that the highest rates of SCD appear to cluster around HD sessions and diminish during nocturnal hours [13]. A small retrospective review of 80 HD patients also demonstrated a 1.7-fold increase in SCD risk in the 12 hours following dialysis [18]. These findings may be explained by rapid fluid and electrolyte shifts during HD which — while correcting pre-dialysis hypertension and hyperkalemia due to significant volume-overload — may also trigger hemodynamic instability and arrhythmogenic episodes.

Interestingly, the difference in arrhythmogenicity between the immediate post-HD period and the other defined intervals was driven primarily by an increased rate of NSVT, rather than the more malignant VA subtypes of VT and VF. This again raises the important question of whether and to what degree the ventricular ectopy observed in the post-HD period is clinically-actionable and, if so, what might be the cardiovascular sequela of this presumed electrophysiologic disarray both acutely and chronically. Continuing to clearly define the

temporal relationships between arrhythmia burden and HD schedule may provide crucial insights into the precise pathophysiologic links between the timing of HD initiation, interdialytic period duration, arrhythmia risk, and SCD. In addition, there is current interest in understanding the role of sensors for dialysate which could impact arrhythmia development and burden. Given that current dialysis prescriptions are fixed with monthly lab monitoring, our data supports the development of dynamic electrolyte sensors and personalized dialysis prescription customized for individual patients. A better mechanistic understanding would lend more insight into strategic research forward.

Our inclusion of only patients with CIEDs is a novel approach to evaluating cardiac rhythms in HD patients. Existing studies investigating the relationships between arrhythmia, SCD, and dialysis schedule have prospectively analyzed HD patients with only ILRs, WCDs, or short-duration cardiac event monitors (e.g. 48-hour Holter monitors). To our knowledge, there have been no studies including patients with CIEDs such as implantable pacemakers (IPMs) and implantable cardioverter-defibrillators (ICDs), and these devices provide several key advantages. First, CIEDs such as pacemakers and defibrillators have much greater memory storage capacity. For example, ILRs generally only store < 1 hour of arrhythmia data per event, and therefore may underestimate highly-frequent arrhythmias [19]. Additionally, ILRs possess only a single lead, which increases the rates of false-positive transmissions and may make ECG interpretation difficult [18]. Not only do CIEDs provide much greater memory capacity, a feature particularly important in the long-term monitoring of patient arrhythmia data, but they also demonstrate excellent discrimination between arrhythmia types [20]. Finally, CIEDs allow for more sophisticated data interpretation, with type, time, and duration data available for each individual event, as well as rate histograms and overall burden of both supraventricular and ventricular events.

Additionally, our study is unique in that it is the first to our knowledge which includes HD patients with known baseline cardiac disease. Given that over 70% of ESRD patients carry comorbid cardiac diagnoses, our cohort seems representative of a real-world practice scenario. Given the multiple shared risk factors between renal and cardiac disease, the inclusion of these patients allows for the study of an important subset of the HD population. Overall, there remains a paucity of data to guide cardiologists in the management of ESRD patients, who will continue to be an important and growing subset of the cardiologist's patient base. The potential for cardiac pharmacological and procedural intervention to potentially improve survival in HD patients first necessitates a deeper understanding of the relationships between renal disease and cardiac arrhythmogenesis.

It should also be noted, however, that our study does have significant limitations. First, our sample size is quite small (44 total patients, 22 of which were on HD), making it difficult to reach the statistical power necessary to find significance for important outcomes such as mortality. Additionally, though our study had excellent female representation (50%), its generalizability is limited by including only HD patients with CIEDs. We may have observed different results had we included patients on peritoneal dialysis or those with other means of monitoring cardiac rhythms (e.g. ILR, WCD, event monitor, etc.). The evaluation of HD patients with CIEDs, though novel, may also introduce an inherent selection bias. Previous studies [13] have demonstrated that only 7.6% of eligible HD patients undergo ICD implantation, which raises the question of whether our population may be skewed toward a healthier population of dialysis patients. It should also be noted that VA detection and therapy may be dependent on device programming, and ideally groups would be analyzed in the context of prospective uniform programming.

Another important consideration in our cohort is that potential confounders existed between groups in that HD patients were more likely to have OSA compared to controls, a known pro-arrhythmic comorbidity. However, the fact that no significant differences existed between groups in VA subtypes nor in AF burden suggests any potential confounding effect was negligible. Finally, the role of dynamic shifts in electrolytes and volume status is unable to be accounted for by the retrospective nature of this study. Dialysis patients receive labs on a monthly basis, yet undergo an average of 12 sessions per month. A better understanding of the fluctuations in potassium and magnesium and the role of dynamic fluid dialysate may portend a promising direction for future research.

CONCLUSION

SCD is a major contributor to mortality in ESRD patients on HD, but the arrhythmogenic mechanisms underlying SCD in this population remain unclear. We have used CIED rhythm analysis to evaluate the differences in VA burden between patients on HD and controls. We found no differences in the prevalence of VA between the two groups, but control patients were more likely to require device therapy. HD patients were most likely to experience any VA in the 12 hours following their most recent HD session compared to other intervals, but the majority of these events were non-sustained. HD patients did not have higher atrial nor ventricular pacing burden compared to controls. Larger studies including HD patients with CIEDs are needed to continue advancing our understanding of the precise pathophysiologic links between SCD, arrhythmia, and ESRD.

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