Vancomycin Use in Patients Requiring Hemodialysis: A Literature Review

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ABSTRACT

Vancomycin, a glycopeptide antibiotic, has remained a popular antimicrobial agent throughout the past five decades, and is often included in empiric antibiotic regimens. With gram-positive coverage, it has found a niche in the treatment of methicillin-resistant Staphylococcus aureus. Although vancomycin has been in existence for many years, questions remain regarding its use. New technologies and practice pattern changes have occurred over the years that altered vancomycin dosing in hemodialysis (HD) patients. Examples of these changes include increased resistance of many organisms, development of high flux HD filters, and reprocessing practices. This review provides a summary of the several concerns that exist in the dosing of vancomycin in HD patients today, and provides a summary table of intradialytic dosing regimens.

Vancomycin is an antibiotic that has been in existence approximately half a century. Although most medications lose their stake in the medical market over that length of time, vancomycin is one exception to this rule. Due to its desirable pharmacokinetic characteristics and excellent coverage of many gram-positive organisms, especially methicillin-resistant Staphylococcus aureus (MRSA), vancomycin remains one of the most commonly administered antibiotics in hemodialysis (HD) patients (1,2).

Despite long-term experience with vancomycin, its use continues to evolve. Over the years, several issues have arisen which have forced change in practice. We review the current concerns that exist regarding vancomycin dosing in HD patients today. These include the ever-changing bacterial resistance patterns; advances in patient technologies (e.g., HD filters and dialyzer reprocessing) and associated impact on dosing, administration, and monitoring; and adverse events associated with vancomycin use.

To Use or Not to Use: Concerns of Resistance

Infection remains a common occurrence and a leading cause of morbidity and mortality in the HD population (3). Because of this high infection rate, antibiotics are frequently administered as either treatment or for prevention of infection in outpatient HD clinics. The chronic use of these medications, especially vancomycin, has been named a culprit in the development of resistant organisms (4). Due to the existence of bacteria that have become fully and partially resistant to vancomycin, the Centers for Disease Control and Prevention (CDC) released guidelines to prevent their further spread and development (5,6). In 1995, the Hospital Infection Control Practices Advisory Committee (HICPAC) released a statement suggesting that vancomycin use should be limited in order to prevent the development of resistant organisms. Guidelines regarding acceptable vancomycin use include: severe beta-lactam-resistant infection, severe allergy to beta-lactam drugs, severe metronidazole-resistant bacterial colitis, endocarditis prophylaxis, and prophylaxis for certain high-risk surgeries (5). In 1997, the CDC issued another statement which focused specifically on the prevention of infections caused by S. aureus with reduced susceptibility to vancomycin. This report again stressed the prudent use of vancomycin (6).

Though most MRSA infections are still susceptible to vancomycin, intermediate and resistant organisms are increasingly common. Alternatives to vancomycin such as daptomycin, quinupristin-dalfopristin, linezolid, and tygecycline are much more costly, and there is less experience with their use. As a result, vancomycin remains a staple in the HD community, so prudent use of the drug is especially important.

Prescribing Practices

Clinical prescribing practices regarding vancomycin have been evaluated for appropriateness in the HD population (1,7). In studies evaluating vancomycin use (1,7), a modified version of the HICPAC guidelines for vancomycin prescribing was used in their evaluations (see...
Factors Affecting Vancomycin Dosing

Several concerns exist regarding proper dosing of vancomycin. There have been many advances to the HD process since vancomycin use became widespread in dialysis patients. Examples include the development of high flux (HF) HD filters, and the practices of reprocessing and reuse of HD membranes. In addition, patient-specific factors such as weight and the presence of residual renal function (RRF) may affect dosing.

Clearance with HF Filters

Advances in technology

Hemodialysis filter technologies are ever-evolving, one aim of which is to increase clearance of larger molecular weight substances (e.g., “middle molecules”). Along with increased middle-molecule removal comes the increased removal of vancomycin, a 1500-Da molecule (2). Vancomycin is not filtered by HD using conventional low flux membranes (e.g., cellulose) (9–11). As a result, traditional dosing recommendations were to give vancomycin once weekly during an HD session without concerns for inadequate serum concentrations. Development of HF membranes has probably improved outcomes in patients, but has complicated dosing of vancomycin by changing its pharmacokinetic profile. While there have been studies regarding the use of vancomycin with conventional dialysis membranes, questions remain concerning dosing in patients using more contemporary filters.

In 2000, the CDC reported that the percentage of patients using HF filters rose from 5% in 1987 to 46% by 1997 (12). In the years since this report, HF filter use may have expanded even more, and for this reason, specific dosing recommendations are needed for patients receiving HF dialysis who require vancomycin therapy.

Contemporary HF filters are constructed of polysulfone (PS), polyacrylonitrile (PAN), or cellulose triacetate (CT), and analysis of vancomycin clearance by each membrane type has been conducted (9,13–25). All studies showed that vancomycin is significantly removed by each of these filter types, but also reconfirmed that there is negligible vancomycin removal with conventional HD filters. Moreover, results have shown that regardless of material used in the construction of these HF HD membranes, vancomycin clearance is equivalent (9). Table 1 provides a summary of vancomycin pharmacokinetic trials during HD using contemporary membranes.

Intradialytic Vancomycin Administration

A commonly debated topic is whether vancomycin is most appropriately dosed by intravenous (IV) infusion “following” HD or “during” HD. Vancomycin must be given as a slow IV infusion to prevent “red man syndrome.” (see Toxicities and Adverse Events) (2) and as conventional dialysis filters commonly used in the past did not adequately remove vancomycin from the blood, the drug could be administered slowly during HD without affecting the dose received by the patient (10,11). This was convenient for both the patient and the outpatient dialysis staff; as it did not prolong the patient’s visit to the HD center. Currently, the majority of HD patients use dialyzers that remove significant amounts of vancomycin. Questions remain whether it is still acceptable to administer the drug during HD, or if post-HD administration is more appropriate. In recent years, several studies have been published with the aim of providing more information on this topic (17–21,23).

In a prospective, randomized, 12-patient study, the use of vancomycin in HD patients using highly permeable membranes constructed of either cellulose...
<table>
<thead>
<tr>
<th>Study (n)</th>
<th>HD characteristics</th>
<th>Filter</th>
<th>BFR/DFR (ml/minute)</th>
<th>Mean length of HD (h)</th>
<th>Residual ClCr (ml/minute/1.73 m²)</th>
<th>Intradialytic half-life (hour)</th>
<th>Dialysis vancomycin clearance (ml/minute)</th>
<th>Dose studied (mg/kg)</th>
<th>Vancomycin dosing recommendations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ariano et al. (21) (n = 22)</td>
<td></td>
<td>F70, F160, or F200 (polysulfone; Fresenius)</td>
<td>350/500</td>
<td>3-5</td>
<td>NL</td>
<td>5.4</td>
<td>NL</td>
<td>1000 (13.6)</td>
<td>Give loading dose of 1 g IV every last hour of HD, and 500 mg over the last hour of each of the following HD sessions</td>
</tr>
<tr>
<td>Foote et al. (19) (n = 5)</td>
<td></td>
<td>F80B (polysulfone; Fresenius); reprocessed with bleach, 1.5% formalin, and heat</td>
<td>400–500/500 (800 for one patient)</td>
<td>3.5-4.6</td>
<td>0</td>
<td>NL</td>
<td>130.7</td>
<td>1388–2375 (25)</td>
<td>Intradialytic dose of 25 mg/kg at 1 g per hour, given over the last portion of HD</td>
</tr>
<tr>
<td>Mason et al. (20) (n = 9; crossover)</td>
<td></td>
<td>CT-190 (cellulose triacetate; Baxter); all filters were new</td>
<td>400/700</td>
<td>3-4</td>
<td>0</td>
<td>5.5 (at 15 mg/kg) 7.9 (at 30 mg/kg)</td>
<td>NL</td>
<td>750–1250 (15) 1750–2500 (30)</td>
<td>If given 15 mg/kg over last 1 hour and anuric- repeat dose on day 5 If given 15 mg/kg post-HD or 30 mg/kg over last 2 hours—repeat dose on day 8</td>
</tr>
<tr>
<td>Zoer et al. (17) (n = 12)</td>
<td></td>
<td>Biospal 2400 (AN69; Hospal, France) or Duoflux high performance (cellulose acetate; CD Medical)</td>
<td>150–250/500</td>
<td>2-6</td>
<td>0-4.8</td>
<td>NL</td>
<td>46</td>
<td>1000 (10.6–18)</td>
<td>No differences were observed between the two filters. 1000 mg during first HD then 500 mg during each subsequent HD</td>
</tr>
<tr>
<td>Scott et al. (18) (n = 8; crossover)</td>
<td></td>
<td>CT-190 (cellulose triacetate; Baxter) or CA-210 (cellulose acetate; Baxter); all filters were new</td>
<td>423/500</td>
<td>3.5</td>
<td>0</td>
<td>NL</td>
<td>NL</td>
<td>1000 (11.3)</td>
<td>Cellulose triacetate filters used for HF HD remove a significant amount of vancomycin, and higher doses of medication may be needed. No specific dosing recommendations were made</td>
</tr>
</tbody>
</table>

HD, hemodialysis; NL, not listed; BFR, blood flow rate; DFR, dialysate flow rate.
Patients received vancomycin 1 g IV following a 2- to 6-hour HD session. Pharmacokinetic modeling predicted that there was no difference found with regard to vancomycin clearance between the two membranes, with the reported clearance for the PAN membrane being 47 ml/minute. Based upon the determined vancomycin pharmacokinetics, the authors recommended vancomycin 1 g IV loading dose over the last hour of HD, and 500 mg IV during each of the following HD sessions. The authors suggest that this dosing regimen would be appropriate not only for anuric patients, but also for those with some RRF.

A study was published which tested the effect of differing HD membranes on intradialytic administration of vancomycin in eight subjects with no RRF (18). The investigation was a crossover design, looking at the vancomycin in eight subjects with no RRF (18). The study was a randomized, crossover trial consisting of three phases. During Phase I, each patient received a 15 mg/kg dose of vancomycin following an HD session. Patients were administered the same dose during Phase II, but it was given during the last hour of HD. In Phase III, 30 mg/kg was given to each patient over the last 2 hours of an HD session. Three weeks separated each phase of the study to allow for a washout period. It was concluded that in order to achieve a serum trough concentration of 10 mg/l, vancomycin could be dosed in one of three ways—15 mg/kg during the final hour of HD and repeated on day 5 of treatment, 15 mg/kg following HD and repeated every 7 days, or 30 mg/kg during the final 2 hours of HD and repeated every 7 days. The investigators also recommended frequent serum concentration monitoring.

More recently, a study in which 22 patients received vancomycin 1 g during the final hour of an HD session, with 500 mg maintenance doses given during the last hour of following sessions was reported (21). Each patient was dialyzed with one of three HF PS filters—the F-70 (1.6 m²), F-160 (1.5 m²), or the F-200 (2.0 m²) (Fresenius, Lexington, MA). Vancomycin trough serum concentrations were determined prior to each HD session, with therapeutic trough concentrations defined as 5–20 mg/l. It was shown that using the above regimen, 96% of the pre-HD concentrations fell within this range, with mean trough concentration being 11 mg/l. There were no significant differences in vancomycin half-life among the three filters used. Pharmacokinetic modeling determined that median intradialytic half-lives of 5.3, 5.1, and 4.9 hours for the F-70, F-160, and the F-200, respectively. Others have reported using the same dosing regimen, except that the doses were given following rather than during the HD session (22). Patients dialyzed with HF PS filters (specific surface area not reported; Fresenius) had very few trough values falling outside the therapeutic range. As both dosing strategies provide therapeutic serum concentrations, intradialytic administration would be favored for its convenience.

Of late, a study determined equivalent vancomycin doses administered during and following HF HD (23). This crossover study involved seven HD patients using a synthetic blend HD filter (Polyflux 24R; Gambro, Lakewood, CO). Each patient received vancomycin 1 g IV following HD, and 1.5 g IV during the final hour of a session following a washout period. It was determined that an intradialytic dose of 1.5-fold greater than a post-HD dose yielded areas under the concentration–time curves that were not significantly different.

While it is easier to predict serum concentrations of vancomycin when the drug is administered to the patient “following” rather than “during” an HD session,
constraints of time and resources favor intradialytic administration, especially in those HD patients treated at an outpatient facility. Clinicians should always be aware of when vancomycin is to be administered to aid in appropriate dosing.

Filter Reprocessing and Reuse

The reprocessing and reuse of HD filters has been shown to change the permeability of the dialysis membrane. Nationwide, much variability exists with respect to dialyzer reuse and reprocessing, with many HD clinics no longer reusing membranes (26). Differences exist regarding the various products used to sterilize filters, as well as the number of times a given filter is reprocessed (27). These factors may change the filterability of the membrane. In 2002, it was reported that 63% of dialysis filters used in the United States were reprocessed and reused. Of these, 73% were processed with peracetic acid. The number reprocessed with formaldehyde had decreased to 20%, and glutaraldehyde and heat represented only a small percentage (27).

Subsequent reuse after reprocessing with peracetic acid-hydrogen peroxide solution (PAHP) (Renalin) decreases the permeability of the membrane, and therefore may decrease vancomycin clearance or clearance of other middle molecules (28). In an in vitro study, the permeability to several substances, including vancomycin, was tested in reprocessed CT or PS HD filters (28). Reprocessing the CT filter 15 times with PAHP significantly decreased vancomycin permeability. The decline in vancomycin filterability did not reach statistical significance for the PS filter, though a downward trend was apparent. (PS filter vancomycin clearances at baseline and after 15 reuses were 135.4 ± 9 ml/minute, and 129.6 ± 9.1 ml/minute, respectively.) With more reuse and reprocessing, as is common in clinical practice (26), this decline may eventually reach statistical significance. The extent of this decrease in filterability will vary depending on the filter; for example with no reuse, the CT190 had a vancomycin clearance of 139.8 ml/minute, and after reuse number 15 the clearance was 120.6 ml/minute. If the predialysis vancomycin concentration was 20 mg/l, and HD lasted 4 hours, the amount lost during that session would differ by 92 mg. With the F80A filter, the loss would have been 28 mg.

The clinical significance of the decrease in filterability with reuse is dependent upon several factors including the vancomycin dose as well as the patient’s size. For example, in a smaller individual, the dose required on a milligram per kilogram basis will be smaller than that for a larger individual to get the same serum concentration. For two different sized patients having the same serum concentrations, a 90-mg difference in dose will have a greater impact in the smaller individual. Therefore, as the number of reuses increases, more monitoring may be necessary, particularly in smaller patients in order to avoid excessive vancomycin doses and potential toxicities.

The use of bleach in the reprocessing procedure can also change the filtration characteristics of a dialyzer. Changes in vancomycin filtration have not specifically been shown to occur following this process. Both PS (F80B; Fresenius) and CT (CT190; Baxter) filters were used in an in vitro analysis of filtration following reprocessing with bleach solution, and vancomycin was used as a predictor of middle molecule removal. (29) Although there were changes in filtration for larger molecular weight substances, reprocessing the membranes up to 15 times had no significant effect on the filterability of vancomycin.

Variability makes it difficult to determine exactly how much vancomycin will be filtered during an HD session. It is important to be aware of reprocessing practices, and to assess the clinical significance, or lack thereof, of changes in permeability on a patient-by-patient basis.

Patient Characteristics Influencing Dosing

Weight-Based Dosing versus Empiric Dosing

Different methods of vancomycin dosing have been studied in both the general population and in HD patients. Currently, there is no consensus as whether to dose the antibiotic based upon weight (in mg/kg) or as an empiric dose (for example, 1000 mg dose regardless of weight). Clinicians commonly use both approaches.

The fixed dose is potentially problematic. For one thing, recent data from United States Renal Data System suggests a steady rise in the average body mass index (BMI) for incident end-stage renal disease (ESRD) patients (Fig. 1) (3). Although in 1995 the average incident BMI was already in the overweight range (2–29.9 kg/m²), current values are much closer to the obese range (≥30 kg/m²) (3,30). In fact, the mean incident BMI in diabetic patients was 29.9 kg/m² in 2005 (3). Recognition of these values becomes increasingly important with regard to drug dosing, vancomycin

![Fig. 1. Mean body mass index (BMI) (kg/m²) over time [adapted from Refs. (3) and (30)].](image-url)
being no exception. Because many pharmacokinetic studies available in ESRD patients are in normal weight individuals, extrapolation of data and estimates are necessary to determine the appropriate dosing regimen in significantly overweight individuals.

Second, data in the general population support the use of total body weight to dose vancomycin rather than ideal body weight (31–34). This holds true for both normal weight individuals, as well as those who are obese. While vancomycin volume of distribution (V_d) is not dependent upon renal function (35), there is a correlation between V_d and body weight (32).

While it may be easier to order the same dose for all HD patients, variability in size, weight, and body composition justify using weight-based regimens. Logically, weight-based regimens have an advantage over empiric dosing when tailoring a dosing regimen to a specific patient. If a 50 kg, 70 kg, and a 90 kg patient were each given a 1-g dose empirically and assuming normal vancomycin V_d of 0.7 mg/l, the resulting estimated serum concentrations would be approximately 28, 20, and 15 mg/ml, respectively, a level of variability that could impact on both the safety and efficacy of the regimen.

Residual Renal Function

Traditional teaching is that most HD patients do not have significant RRF after 1 year of dialysis. However, this is no longer the case. Current practices may lead to the initiation of HD earlier than in past years, resulting in patients new to HD having creatinine clearances up to 15 ml/minute and maintenance of RRF well past the 1 year mark. In addition, better biocompatibility of dialyzers and dialysate are believed to have favorably impacted the decline of RRF.

The impact of RRF can be estimated using data from earlier studies with conventional HD filters that removed little vancomycin. For example, using an equation derived by Matzke et al. (intrinsic vancomycin clearance = 0.689 × CrCl (ml/minute) + 3.66) (11) a patient with a creatinine clearance of 0, 5, 10, or 15 ml/minute would have a vancomycin renal clearance of approximately 0, 7, 11, or 14 ml/minute, respectively. Increasing clearance would necessitate either an increased vancomycin dose or decreased time between doses. Given that an HD patient comes to the facility three times a week (approximately every 48 hours) the vancomycin dose would need to be increased.

For example, in a 70 kg person with 0 ml/minute RRF, an administered vancomycin dose of 1 g would result in a vancomycin trough of 16 mg/l. If the patient had RRF of 15 ml/minute, the same dose would result in a 9 mg/l vancomycin trough concentration. Therefore, maintenance of a vancomycin trough concentration of 16 mg/l in 70 patients with residual creatinine clearances of 0, 5, 10, or 15 ml/minute would require doses of 1000, 1200, 1400, or 1760 mg, respectively. Thus, vancomycin concentrations may be lower than expected in patients with intrinsic clearance if one uses dosing guidelines for anuric patients. Clinicians need to be aware of a patient's RRF and appropriately adjust vancomycin doses.

Monitoring Serum Vancomycin Concentrations

Traditionally, vancomycin serum concentrations were frequently monitored in order to prevent possible toxicities, though data are limited to support this practice (36). In recent years, several investigations have sought to decrease superfluous dose adjustments and monitoring (22,31). Pai and Pau (22) presented a limited-sampling algorithm for thrice-weekly HD patients in which serum concentrations were drawn pre-HD on specified days. During a given treatment course, an average of just seven samples were collected for each patient. Using the parameters of 5–20 mg/l for trough concentrations, it was found that 93% of trough concentrations fell within these limits.

Treatment failure with vancomycin is frequently attributed to subtherapeutic dosing. For this reason, clinicians may sometimes choose to dose patients to higher trough concentrations than the previously recommended 5–10 or 5–20 mg/l. The latest Guidelines for the Management of Adults with Hospital-Acquired, Ventilator-Associated, and Healthcare-Associated Pneumonia, recommend that trough concentrations be kept between 15 and 20 mg/l (37). Previously described dosing algorithms cannot be used to achieve such a narrow range of vancomycin concentrations (21,22).

Although frequent vancomycin monitoring is not generally recommended, there are certain clinical situations in which it may be appropriate. There are several circumstances in which there is a lack of information regarding appropriate dosing; examples include dosing in morbidly obese individuals, those on HD with significant RRF, patients using membranes reprocessed more than 15 times, and those with life-threatening infections, or infections with intermediate susceptibility to vancomycin requiring high trough concentrations.

Rebound Following HD

Although a significant amount of vancomycin is removed during HF HD, the absolute amount filtered has been shown to be overestimated by early trials as vancomycin serum concentration rebound following a treatment session was not recognized (13–15). The clinician should be aware of the rebound of vancomycin serum concentration that occurs following HD as it is important not only in study design, but also when monitoring a patient in clinical practice. Estimations of plasma concentrations should not be based upon concentrations drawn immediately following HD (24,25).

In one study, nine inpatients were given 15 mg/kg of IV vancomycin and dialyzed for 2 hours (BFR 400 ml/minute) approximately 24 hours later with an F-80 (1.9 m²) (Fresenius) PS filter (24). During the session, investigators noted a decrease in serum vancomycin concentration to 67% of pre-HD concentrations; however, concentrations rose to 87% of pre-HD concentrations by an average of 6 hours post-HD. Later, another study provided further evidence that the rebound which occurs has not only temporal variability, but is inconsistent in percent rebound, as well (25).
Interpretation of Vancomycin Concentration

There are several methods available to measure serum vancomycin concentrations (38–40). Concerns exist that as renal function declines, the accuracy of some of these assays is lost. Because vancomycin is a renally excreted medication, its half-life is prolonged in patients with decreased kidney function. It has been shown that this extended exposure to body temperature and to relative acidity can lead to accumulation over several weeks of an inactive compound called the crystalline degradation product (CDP) (40). It has been suggested that this compound interferes with some of the available assays used in measuring vancomycin serum concentrations (39,41–47). In HD patients, this is an important consideration. As CDP may cause a falsely elevated vancomycin concentration to be reported, clinicians may interpret trough concentrations as being too high, and decrease or hold doses of needed antibiotic.

Several methods have been utilized to measure serum concentrations of vancomycin. These include high-performance liquid chromatography, enzyme multiplied immunoassay technique, radioimmunoassay, and fluorescence polarization immunoassays (FPIA) (38). FPIA may be further broken down to the older polyclonal FPIA (pFPIA) and the newer monoclonal FPIA (mFPIA) (45). In 1998, the most commonly used technique was FPIA (46). Some FPIA methods are also associated with cross-reactivity with CDP. Further, several different FPIAs are commercially available today (39,40).

Depending on the assay used in determining the serum vancomycin concentration, clinicians should be aware of the potential for cross-reactivity with CDP. As this interaction has been identified, most manufacturers of vancomycin assay kits have tested for the interaction of CDP with the assay (39,40). While testing indicated that there is not an interaction with some assays, for example Abbott’s Vancomycin II (mFPIA, Abbott Laboratories, Abbott Park, IL) (41), using certain other assays in the presence of CDP will cause significant interaction, for example Abbott’s Vancomycin assay (pFPIA) (39).

With many options available for serum concentration monitoring, the clinician should be aware of the potential for CDP interaction with various assays commercially available. If, for example, a patient’s serum concentration of vancomycin seems to be increasing over time rather than decreasing, or not decreasing at the rate expected, the assay procedure should be examined.

Toxicities and Adverse Events

Patients who receive vancomycin may experience several types of adverse reactions including anaphylaxis and red man syndrome (RMS). The risk of anaphylaxis, a dose-independent side effect, is small with vancomycin, but nevertheless may occur. More commonly, the phenomenon of RMS appears during treatment with vancomycin. This side effect manifests as erythema of the head and neck, hypotension, pruritus, and tachycardia. RMS often arises when the drug is infused too rapidly, and is thought to be caused by histamine release (2). The reported incidence of RMS ranges from 3% to up to 50% in infected patients, and seems to be much higher when healthy individuals are given the drug (48,49). The risk of RMS is decreased by giving a slow infusion over 1 hour, though some data suggest giving the medication even slower. In a crossover study of 10 healthy volunteers, vancomycin 1 g was infused over either 1 or 2 hour intervals (50). The 2 hour infusion was associated with significantly lower histamine release and fewer and less severe cases of RMS.

Ototoxicity and nephrotoxicity have been rarely reported with vancomycin (2), but most reports were from several decades ago when vancomycin was available in an unpurified form commonly referred to as “Mississippi mud.” Although the impurities found in this formulation are not proven ototoxins (36), the possibility exists. There have been several more recent case reports of ototoxicity (51,52). While auditory toxicity is rare with monotherapy, it is possible that concomitant receipt of other ototoxic medications may augment hearing loss.

Nephrotoxicity is a concern for those HD patients who have some RRF. While nephrotoxicity with monotherapy of vancomycin is very rare, the combination of vancomycin with aminoglycoside antibiotics greatly increases this risk (53). Other side effects associated with vancomycin may include phlebitis at injection site, pseudomembranous colitis, and a reversible neutropenia. The latter is rare, usually manifests after at least a week of therapy, typically with a total dose of 25 g of vancomycin in patients with normal renal function (2). The impact of total dosage in the chronic kidney disease population is uncertain.

Conclusions

Vancomycin is one of the most commonly administered antibiotics in HD clinics (1), and its use has been extensively studied. Despite five decades of use, the single best method to administer vancomycin during HD remains elusive. As the HD practices of today are much different from those of the past, many initial vancomycin studies lack relevant information. Technologies continue to evolve, and for this reason, there remains a need for updated studies with the most recent and prevalent practice patterns in mind.

References
