Clearance of Vancomycin during High-Efficiency Hemodialysis

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Background: *Vancomycin is commonly used for the treatment of MRSA infections in critically ill patients with renal diseases. Vancomycin is mainly eliminated through the kidney. Its excretion is therefore substantially reduced in severe renal impaired patients. Although several studies have demonstrated that significant amounts of vancomycin are removed during High-Flux/High-Efficiency Hemo Dialysis (HF/HEHD), more data are required to optimize clinical applications.*
Objective: *Predict the appropriate vancomycin intradialytic dosage and dosing interval among patients receiving HEHD.*
Material and Method: *Twenty patients who were receiving HEHD with cellulose triacetate dialyzer were included to determine the vancomycin intradialytic clearance. Two patients were included twice and one patient was included three times due to reinfections. This gave rise to 24 patient-times. The study was carried out at Songklanagarind Hospital between January 2003 and March 2004.*
Results: *In a prospective opened label design, each patient received 1g vancomycin, 1 hour infusion, immediately after completion of HEHD. Six scheduled blood samples were drawn as follows: (1) 60 minutes following completion of vancomycin infusion (C_{max}); (2) immediately before starting the second HEHD; (3) 2 hours after starting the second HEHD; (4) immediately after completion of the second HEHD; (5) immediately before starting the third HEHD; and (6) immediately after the third HEHD ended (C_{min}). The authors measured vancomycin serum levels using HPLC technique. The serum concentrations were used to calculate all relevant pharmacokinetic parameters. The pharmacokinetic parameters (mean SD) were: intradialytic clearance (CL_{HD}) 93.4 37.1 mL/min; intradialytic elimination rate constant (k_e) 1.1 0.5 hr^{-1}; overall elimination half-life ($t_{1/2}$) 77.1 37.8 hr; volume of distribution (V_d) 82.1 40.3 L; C_{max} 25.8 8.12 mg/L (range 12.04-48.80); C_{min} 6.2 3.1 mg/L; and % removal during the second HEHD 37.9 12.9. Subtherapeutic levels were found in 66.7% (16/24) and 91.6% (22/24) of patients after the second and the third HEHD, respectively.*
Conclusion: *HEHD with cellulose triacetate dialyzer removes significant amount of vancomycin. Based on the authors' findings, a loading dose of 1 g, and 500 mg after every subsequent HEHD is recommended.*

Keywords: *Clearance, Hemodialysis, Vancomycin, Pharmacokinetics*

J Med Assoc Thai 2006; 89 (7): 986-91
Full text. e-Journal: *http://www.medassocthai.org/journal*

Vancomycin is a glycopeptide antimicrobial agent commonly used for the treatment of MRSA infections. Vancomycin is mainly eliminated by glomerular filtration. The clearance of the drug significantly decreases in patients with impaired renal function and is absent in anuric patients. The recommended dosage for anuric patients undergoing hemodialysis is 1 g every 5 to 7 days[1]. High-Flux/High-Efficiency Hemo Dialysis (HF/HEHD) substantially reduces serum vancomycin concentration as it removes a significant amount of vancomycin[2-9].

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The present study aimed to determine vancomycin intradialytic clearance and to find an appropriate dosage for patients receiving HEHD.

Material and Method

The study protocol was approved by the Ethics Committee of Songklanagarind Hospital, Faculty of Medicine, Prince of Songkla University (reference number 46/400-002). Written informed consent was given by each patient prior to participation in the present study.

Subjects

Criteria for inclusion: In- and out-patients who were treated by HEHD and were prescribed vancomycin.

Criteria for exclusion: Patients who developed or had a previous history of hypersensitivity to vancomycin, or had vancomycin administration within the past month.

Criteria for termination: Patients who could no longer participate in the present study because they had died, stopped vancomycin administration and/or referral to other hospitals.

In- and out-patients with renal failure who were treated by HEHD and prescribed vancomycin for infectious therapy or prophylaxis were included in the present study. Each patient received 1g vancomycin intravenous infusion over 1 hour after the first HEHD was completed. Six 5-mL-blood samples were drawn for measurement of serum vancomycin concentrations at the following time points: (1) at 60 minutes after completion of vancomycin infusion (C_{max}); (2) immediately before starting the second HEHD (C_{preHD2}); (3) 2 hours after starting the second HEHD ($C_{2hr, HD2}$); (4) immediately after completion of the second HEHD ($C_{postHD2}$); (5) before starting the third HEHD (C_{preHD3}); and (6) immediately after the completion of the third HEHD (C_{min}). Blood levels at point (2), (3), and (4) were required for calculation of intradialytic elimination rate constant (k_e). Individual's UF goal and hemodialysis conditions were designed according to the patient's renal function or clinical signs and symptoms. All patients were followed-up for three consecutive HEHD sessions. Overall follow-up time among patients was, however, different, and was based on the weekday that the patients received the first HEHD. The cellulose triacetate dialyzer, Nipro® Fisoe dialyzer, with membrane surface area 1.5 m^2 and ultrafiltration coefficient (K_{uf}) 20.5 mL/hr/mmHg was used. Blood samples were centrifuged at 3000 G for 10 minutes. The serum portion was separated and stored at -20°C until analysis. Serum vancomycin concentrations were measured by reverse phase high-performance liquid chromatography (HPLC)[6]. 100 mL of the serum was transferred to a 1.5 mL centrifuge tube. 50 mL of the internal standard hydrochlorothiazide (HCTZ) and 100 mL of methanol were added, mixed and centrifuged at 15,000 G for 10 minutes[7]. 20 mL of the supernatant was injected into the HPLC system.

The HPLC system consisted of a Jasco UV-975 intelligent UV visible detector, and Jasco PU-1580 intelligent HPLC pump, made in Japan. ThermoHypersil-Kevstone BDS Hypersil C18, 150 × 4.6 mm column was used as the stationary phase; the mobile phase was composed of 10% acetonitrile in a 25 mmol/L phosphate buffer (potassium phosphate, monobasic/ phosphoric acid, pH 7.0). The detection wavelength was 229 nm. At flow rate of 1.5 mL/min, the retention times of the internal standard HCTZ and vancomycin were 5 and 9 minutes, respectively. The quantification was based on the ratio of peak area and retention time of vancomycin to the internal standard HCTZ. The lower limit of detection was at 2 mg/L. Intra-day variabilities (coefficients of variation) of 3 vancomycin concentrations i.e., 2, 15 and 50 mg/L were 11.59%, 11.94% and 9.86%, respectively, and the corresponding inter-day variabilities were 17.95%, 5.11% and 7.91%, respectively. Ranges of recovery percentage of 5 replications of vancomycin at concentrations 2, 15 and 50 mg/L lay between 93.16 and 102.87%. As the system studied was quite complex, pharmacokinetic parameters of vancomycin were calculated using 3 methods. The volume of distribution (V_d), and the overall elimination half-life ($t_{1/2}$) of vancomycin was calculated by WinNonlin program, using all 5 serum vancomycin concentration data. The authors plotted a semilogarithmic graph of three serum vancomycin concentrations (C_{preHD2}, $C_{2hr,HD2}$ and $C_{postHD2}$), collected during the second HEHD, versus time to determine the intradialytic elimination rate constant (k_e) of the system. The authors calculated vancomycin intradialytic clearance (CL_{HD}) for each patient using the hemodialysis flow model as shown in Equation 1, the C_{preHD2} and $C_{postHD2}$ were required for the calculation[4].

$$Q_{pa} = Q_a (1\text{-Hct})$$
$$Q_{pv} = Q_{pa} - UFR$$
$$CL_{HD} = [(Q_{pa} \times C_{preHD2}) - (Q_{pv} \times C_{postHD2})] / C_{postHD2} \quad \text{(Equation 1)}$$

where, $C_{postHD2}$ = vancomycin concentration immediately after completion of the second HEHD

C_{preHD2} = vancomycin concentration just prior

to starting the second HEHD

CL_{HD} = intradialytic clearance
Hct = hematocrit (%)
Q_a = arterial blood flow rate
Q_{pa} = arterial plasma flow rate
Q_{pv} = venous plasma flow rate
UFR = ultrafiltration rate

Data analysis

To provide an ability to estimate vancomycin intradialytic clearance of a patient without additional blood sample collection in the future, the authors performed a linear regression model using theoretical determinants, which were routinely investigated, i.e., the urea reduction ratio (URR), creatinine reduction ratio (CrRR), blood flow (Q), UFR and hemodialysis treatment time. The authors obtained the model, as shown below, with R-square 52.5% and p-value 0.0323. A p-value < 0.05 was considered significant.

CL(mL/min) = 2.61[%URR] – 1.55[%CrRR] + 0.30[Q(mL/min)] – 0.57[time(hour)] – 7.28[UFR(L/hour)] – 75.42

In addition, a supplement dose of vancomycin was determined by the apparent % removal of vancomycin during HEHD. Increased vancomycin levels after HEHD due to redistribution, have been reported. Mean post-dialysis redistribution time of vancomycin is 3 and 6 hours (range 1 to 12 hours)[10,11]. Failure to determine the extent of post-dialysis redistribution may lead to an underestimation of post-HEHD vancomycin level and excess dosage supplementation. The authors determined apparent % removal (at the end of HEHD) using Equation 2. The present design precluded the ability to determine post-dialysis vancomycin redistribution. The authors, however, tried to calculate post-rebound % removal by substituting the post-dialysis rebound concentration with C_{preHD3}. The authors therefore determined%removal by comparing C_{preHD3} with C_{preHD2} as given in Equation 3.

$$\text{Apparent \% removal} = [(C_{preHD2} - C_{postHD2}) / C_{preHD2}] \times 100 \quad \text{(Equation 2)}$$

$$\text{Post-rebound \% removal} = [(C_{preHD2} - C_{preHD3}) / C_{preHD2}] \times 100 \quad \text{(Equation 3)}$$

The authors did not design to measure the extent of residual renal function on vancomycin clearance based on an assumption that HEHD was used in any patient whose renal function was very small and could be negligible. The authors, however, observed that changes in serum vancomycin concentrations during interdialytic period were not different between ARF and CRF patients.

The authors calculated the supplement dose of vancomycin intravenous infusion within 1 hour post-HEHD using Equation 4.

$$\text{Dose (mg)} = [(C_{desire})\ (CL_{HD} * 60 \text{ min})\ (\text{dialysis treatment time})] / 1{,}000 \quad \text{(Equation 4)}$$

where, C_{desire} (mg/L), CL_{HD} (mL/min/1000), dialysis treatment time (hr)

Results

Table 1 summarizes demographic data of the studied subjects. Six patients (1 referral and 5 dead) out of 26, dropped out from the present study resulting in twenty patients available for data analysis. Of these, two patients were included twice and one patient was included three times because they were prescribed vancomycin for treatment of reinfections. The authors therefore had 24 patients-time samples of vancomycin serum concentration data. These observations in repeated subjects were treated as independent samples because the individual's HEHD conditions varied each time. Eight patients (2 males and 6 females) were ARF associated with systemic lupus erythematosus and twelve patients were CRF (5 males and 7 females). The blood flow rates ranged from 200 to 400 mL/min, i.e., 200 mL/min in one patient; 300 mL/min in seven patients; 350 mL/min in nine patients; and 400 mL/min in seven patients. The dialysis treatment time also varied among patients i.e., 4 hours in seventeen patients; 5 hours in six patients; and 4.5 hours in one patient.

Table 2 presents pharmacokinetic parameters of vancomycin. During HEHD, the serum vancomycin concentrations declined rapidly due to intradialytic clearance, from predialysis level of 25.3 ± 8.1 to 6.3 ± 3.1 mg/L at the end of HEHD. The maximum serum vancomycin concentrations (range 12.0-47.8 mg/L) did not reach the toxic levels (therapeutic range 10-50 mg/L), but the vancomycin concentrations (range 5.1-17.6 mg/

Table 1. Demographic data of study subjects and hemodialysis conditions

Variable	Mean ± SD (range), n = 24
Age (year)	52.5±15.8 (22-76)
Weight (kg)	51.5±7.8 (41-72)
Laboratory results	
BUN (mg/dl)	62.7±25.8 (30.9-135.0)
Serum creatinine (mg/dl)	6.7±3.7 (2.6-14.4)
Creatinine clearance (mL/min)	11.9±8.9 (1.6-10.4)
UF goal (L)	2.7±1.1 (1.0-5.0)

Table 2. Pharmacokinetic parameters of vancomycin during high-efficiency hemodialysis in patients with renal failure

Parameter	mean ± SD (range), n = 24	Parameter	mean±SD (range), n = 24
CL_{HD} (mL/min)	93.4±37.1 (30.8-167.5)	C_{preHD2} (mg/L)	13.6±6.5 (5.8-33.2)
k_e (hr^{-1})	1.1±0.5 (0.5-2.6)	C_{2hrHD2} (mg/L)	11.0±6.3 (2.9-29.6)
$t_{1/2}$ (hr)	77.1±37.8 (42.6-171.9)	$C_{postHD2}$ (mg/L)	8.9±4.9 (2.6-24.3)
V_d (L)	82.1±40.3 (30.2-162.5)	C_{preHD3} (mg/L)	8.5±4.4 (3.9-18.4)
C_{max} (mg/L)	25.3±8.1 (12.0-47.8)	C_{min} (mg/L)	6.2±3.1 (2.6-20.0)

CL_{HD} = intradialytic clearance
k_e = intradialytic elimination rate constant
$t_{1/2}$ = overall patients' elimination half-life, Vd = volume of distribution

L) were below therapeutic levels in 66.7% (16/24) of patients after the second HEHD. Post-dialysis rebound concentrations were not assessed in the present study. The authors, however, observed that $C_{postHD2}$ and C_{preHD3} were very similar. This led to equivalent vancomycin apparent % removal and post-rebound % removal (37.6 ± 13.9 and 37.9 ± 12.9%, respectively). $C_{postHD2}$ might be a good indicator of C_{preHD3} that may help design vancomycin dosage regimen in patients receiving HEHD. At the end of the third HEHD, only two patients had therapeutic vancomycin levels. Supplement dosage (mean ± SD), calculated using the Equation 4, to achieve the serum vancomycin concentration of 25 mg/L was 598.2 ± 244.5 mg. The authors, therefore, recommended a practical dosage of 500 mg vancomycin after a subsequent HEHD to provide an average serum vancomycin concentration of 22.2 ± 6.3 mg/L.

Discussion

The results of the present study indicate that a single 1 g vancomycin dosing is not sufficient for a 5-7 days treatment in patients undergoing HEHD. The regression model, using URR, CrRR, blood flow rate, UFR and dialysis treatment time as predictors of intradialytic clearance, can substantially explain the variance of intradialytic clearance (53%). Even though some factors did not significantly predict the clearance, but they theoretically determined intradialytic clearance. This model may be practically useful since the determinant variables are routinely investigated. Using this model as a rough estimation of vancomycin clearance can avoid additional blood sample collection.

Pharmacokinetic study of vancomycin in patients treated with HEHD was designed differently. DeSoi estimated total vancomycin removal during 3 to 4 hours hemodialysis with different membranes. He measured both apparent removal (at end of HFHD) and post-rebound removal of vancomycin[2]. He found (mean ± SEM) apparent % removal 43.1 ± 9.3 and post-rebound % removal 22.0 ± 4.0 in four patients treated with cellulose triacetate membrane. These corresponding figures for other membranes were: polyacrylonitrile 34.5 ± 3.1 and 25.4 ± 4.0; polysulfone 42.8 ± 2.8 and 29.9 ± 4.4; and cuprophane (a classical membrane) 5.6 ± 1.9 and 5.8 ± 3.8. Based on this observation, post-rebound removal was approximately 20% less than the apparent removal when cellulose triacetate was used. Another study on pharmacokinetics of vancomycin during dialysis with polysulfone demonstrated that intradialytic removal ranged from 39.1% to 55.1%, mean intradialytic clearance 130.7+30.0 mL/min, and post-dialysis serum vancomycin concentrations ranged from 8.14 to 10.1 mg/L[3]. A study on pharmacokinetics of vancomycin (1 g) infused over the last hour of HEHD with cellulose triacetate reported the $AUC_{(0\text{-}44\ hours)}$ of 74% compared with that found when the same dose was administered after dialysis in the same patients[7].

Intradialytic clearance is an important factor determining post-dialysis supplement dosage of vancomycin. A study of 6 hemodialysis patients receiving 1 g of vancomycin, immediately after the completion of a routine dialysis session, found a mean intradialytic vancomycin clearance of 56.7 ± 7.5 mL/min with the cellulose triacetate-110 and 100.7 ± 10.7 mL/min with the cellulose triacetate-190 membranes[11]. On the basis of post-rebound concentrations, the % removal of vancomycin was 23.6 ± 1.2 and 25.2 ± 8.6 for cellulose triacetate-110 and cellulose triacetate-190 membranes[11]. The amount of vancomycin removed should be replaced after HEHD to prevent a subtherapeutic level. Concerning the post-dialysis rebound, a substituted dose calculated using post-rebound concentration might be more appropriate. The present study adds to the evidence that vancomycin is removed in a significant amount during HEHD, and the amount removed is consistent with those previously reported.

The authors found C_{preHD3} in 9 observations were slightly higher than $C_{postHD2}$. This event may be explained by a redistribution of vancomycin in the body. Because the present design did not allow the authors to quantify post-dialysis rebound, this phenomenon was not observed among the remainder. The V_d of vancomycin is usually altered in patients with renal failure partly because of changes in plasma protein-binding, 18% increases in V_d can be found (the usual protein-binding was normally 50-60%)[1]. In patients with low plasma protein-binding, unbound vancomycin fractions even increased and were then removed mostly by hemodialysis.

The authors had some limitations in the present study, the small number of patients recruited in the study period, as well as dialyzer condition (new/reused). Some participating patients were dropped out from the study because they died, or were referred to other hospitals. Differences in dialyzer conditions were, however, minimized as the dialyzers with priming volumes of not less than 80% were used in the present study. The authors' design did not provide ability to measure the extent of residual renal function on vancomycin clearance or post-rebound concentration. Calculated supplement dosage is probably slightly overestimated, but serious adverse effects would be very unlikely to occur.

Based on the authors' findings as well as other supporting evidence, a loading dose of 1 g vancomycin through intravenous infusion post-HEHD and a 500 mg infusion with every subsequent dialysis, should be recommended for patients undergoing HEHD with cellulose triacetate dialyzers.

References

1. McEvoy GK. AHFS drug information 2001. Wisconsin: American Society of Health-System Pharmacists; 2001.
2. DeSoi CA, Sahm DF, Umans JG. Vancomycin elimination during high-flux hemodialysis: kinetic model and comparison of four membranes. Am J Kidney Dis 1992; 20: 354-60.
3. Foote EF, Dreitlein WB, Steward CA, Kapoian T, Walker JA, Sherman RA. Pharmacokinetics of vancomycin when administered during high flux hemodialysis. Clin Nephrol 1998; 50: 51-5.
4. Hudson JQ, Comstock TJ, Feldman GM. Evaluation of an in vitro dialysis system to predict drug removal. Nephrol Dial Transplant 2004; 19: 400-5.
5. Mason NA, Neudeck BL, Welage LS, Patel JA, Swartz RD. Comparison of 3 vancomycin dosage regimens during hemodialysis with cellulose triacetate dialyzers: post-dialysis versus intradialytic administration. Clin Nephrol 2003; 60: 96-104.
6. Quale JM, O'Halloran JJ, DeVincenzo N, Barth RH. Removal of vancomycin by high-flux hemodialysis membranes. Antimicrob Agents Chemother 1992; 36: 1424-6.
7. Schaedeli F, Uehlinger DE. Urea kinetics and dialysis treatment time predict vancomycin elimination during high-flux hemodialysis. Clin Pharmacol Ther 1998; 63: 26-38.
8. Scott MK, Mueller BA, Clark WR. Vancomycin mass transfer characteristics of high-flux cellulosic dialysers. Nephrol Dial Transplant 1997; 12: 2647-53.
9. Touchette MA, Patel RV, Anandan JV, Dumler F, Zarowitz BJ. Vancomycin removal by high-flux polysulfone hemodialysis membranes in critically ill patients with end-stage renal disease. Am J Kidney Dis 1995; 26: 469-74.
10. Pollard TA, Lampasona V, Akkerman S, Tom K, Hooks MA, Mullins RE, et al. Vancomycin redistribution: dosing recommendations following high-flux hemodialysis. Kidney Int 1994; 45: 232-7.
11. Welage LS, Mason NA, Hoffman EJ, Odeh RM, Dombrouski J, Patel JA, et al. Influence of cellulose triacetate hemodialyzers on vancomycin pharmacokinetics. J Am Soc Nephrol 1995; 6: 1284-90.
12. Lucksiri A, Scott MK, Mueller BA, Hamburger RJ, Sowinski KM. CAHP-210 dialyzer influence on intra-dialytic vancomycin removal. Nephrol Dial Transplant 2002; 17: 1649-54.

อัตราการกำจัดยา vancomycin ขณะทำ high-efficiency hemodialysis

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Vancomycin เป็นยาที่ถูกใช้บ่อย ๆ สำหรับรักษาการติดเชื้อแบคทีเรีย MRSA ในผู้ป่วยโรคไต เนื่องจาก vancomycin ถูกกำจัดทางไตเกือบทั้งหมด เมื่อผู้ป่วยมีการทำงานของไตบกพร่องอย่างรุนแรง การกำจัดยานี้ออกจากร่างกายจะลดลงมาก มีรายงานว่า high-flux/high efficiency hemodialysis (HF/HEHD) กำจัดยา vancomycin ออกจากร่างกายอย่างมีนัยสำคัญ การศึกษานี้มีวัตถุประสงค์เพื่อหาอัตราการกำจัด (clearance) ของ vancomycin ใน ผู้ป่วยที่ได้รับการรักษาด้วย HEHD เพื่อกำหนดแนวทางการปรับขนาดยา vancomycin ให้เหมาะสม โดยทำการศึกษา ในผู้ป่วยติดเชื้อ MRSA 20 ราย ที่เข้ารับการรักษาด้วยเครื่องไตเทียมที่ใช้เมมเบรนชนิด cellulose triacetate ณ โรงพยาบาลสงขลานครินทร์ ระหว่างเดือนมกราคม พ.ศ. 2546 ถึงเดือนมีนาคม พ.ศ. 2547 โดยหลังเสร็จสิ้นการทำ HEHD ครั้งแรก ผู้ป่วยได้รับยา vancomycin ขนาด 1 กรัม ฉีดเข้าหลอดเลือดดำนาน 1 ชั่วโมง มีการเจาะเลือดผู้ป่วยตามเวลาที่กำหนด จำนวน 6 ครั้ง ดังนี้ (1) ระดับยาสูงสุดที่ 1 ชั่วโมงหลังเสร็จสิ้นการได้รับยา (2) ก่อนเริ่มทำ HEHD ครั้งที่ 2 (3) 2 ชั่วโมงหลังเริ่มการทำ HEHD ครั้งที่ 2 (4) เมื่อเสร็จสิ้นการทำ HEHD ครั้งที่ 2 (5) ก่อนเริ่มทำ HEHD ครั้งที่ 3 และ (6) เมื่อเสร็จสิ้นการทำ HEHD ครั้งที่ 3 การศึกษานี้เก็บข้อมูลทั้งหมดจำนวน 24 คน-ครั้ง (ผู้ป่วยทั้งหมด 20 คน โดยผู้ป่วย 17 คน เก็บข้อมูลคนละ 1 ครั้ง ผู้ป่วย 2 คน เก็บข้อมูลคนละ 2 ครั้ง และผู้ป่วย 1 คน เก็บข้อมูล 3 ครั้ง เนื่อง จากมีการติดเชื้อซ้ำ) วิเคราะห์หาระดับยา vancomycin โดยวิธี HPLC และคำนวณค่าพารามิเตอร์ทางเภสัชจลนศาสตร์ของระบบ พบว่า ค่าพารามิเตอร์ (ค่าเฉลี่ย $\pm$ ค่าเบี่ยงเบนมาตรฐาน) มีดังนี้ อัตราการกำจัดยา vancomycin ขณะ รักษาด้วยเครื่องไตเทียมครั้งที่ 2 (CL_{HD}) 93.4 $\pm$ 37.1 มิลลิลิตร/นาที ค่าคงที่การกำจัดยาขณะรักษาด้วยเครื่องไตเทียมครั้งที่ 2 (k_e) 1.1 $\pm$ 0.5 ชั่วโมง$^{-1}$ ค่าครึ่งชีวิตการกำจัดยารวม ($t_{1/2}$) 77.1 $\pm$ 37.8 ชั่วโมง ปริมาตรการกระจายยา (V_d) 82.1 $\pm$ 40.3 ลิตร ระดับยาสูงสุด 25.8$\pm$8.1 มิลลิกรัม/ลิตร (12.0-48.8) และระดับยาต่ำสุดหลังทำ HEHD ครั้งสุดท้าย 6.2 $\pm$ 3.1 มิลลิกรัม/ลิตร (2.6-20.0) พบว่าหลัง HEHD ครั้งที่ 2 มีการกำจัดยาร้อยละ 37.9 $\pm$ 12.9 ผู้ป่วยที่มีระดับยาต่ำกว่าช่วงการรักษาหลังการทำ HEHD ครั้งที่ 2 และ ครั้งที่ 3 คิดเป็นร้อยละ 66.7 (16/24) และ 91.6 (22/24) ตามลำดับ ผลการศึกษาชี้ว่า ปริมาณ vancomycin ถูกกำจัดออกอย่างมีนัยสำคัญ และแนะนำว่าผู้ป่วยควรได้รับยา vancomycin ขนาดเริ่มต้น 1 กรัม และได้รับยาซ้ำขนาด 500 มิลลิกรัม หลัง HEHD แต่ละครั้ง