The Impact of Nurse Understaffing on the Transmission of Hepatitis C Virus in a Hospital-Based Hemodialysis Unit

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Key Words

Nurse understaffing · Hemodialysis · Hepatitis C virus · Nosocomial transmission

Abstract

Objective: To determine the impact of nurse understaffing on the transmission of hepatitis C virus (HCV) infection in a large hospital-based hemodialysis (HD) unit with a high HCV prevalence. **Subjects and Methods:** The records of 198 patients (107 males and 91 females) with end-stage renal disease enrolled on long-term HD at King Fahad Hospital and Tertiary Care Center, Hofuf, Saudi Arabia, from August 1995 to August 2000, were retrospectively reviewed. The patients were assigned to HD groups of varying patient-to-nurse (P/N) ratios: group I, 2:1; group II, 3:1, and group III, 4:1. HCV prevalence, seroconversion rates, history of blood transfusion and dialysis age (time span since the initiation of the HD treatment) were recorded and compared. **Results:** The overall HCV prevalence and seroconversion rate per year were 43.4 and 8.6%, respectively. Group I had the lowest HCV prevalence and annual seroconversion rate (26.8%; 5.3%), followed by group II (43.6%; 8.7%); group III had the highest HCV prevalence and seroconversion rate (71.8%; 14.4%). Anti-HCV positivity was associated with

a higher dialysis age. **Conclusion:** The finding that the patients in the groups with the relatively higher P/N ratio had the significantly higher HCV prevalence and seroconversion rates per year indicates that understaffing is likely to play a major role in the transmission of HCV in HD units, and we suggest that improved staffing may be helpful in reducing the HCV transmission in such dialysis units.

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Introduction

Hepatitis C (HCV) infection, widespread on a global scale, has become a major cause of morbidity and mortality in patients on long-term hemodialysis (HD), including those in Middle Eastern countries [1–3]. The growing burden of HCV infection for immunocompromised patients on HD is of particular concern due to the increased risk of chronic liver disease, complications in renal transplantation and death – along with the enormously high cost of the management of end-stage renal disease (ESRD) [3].

Nosocomial infection has been reported to be the principal mode of HCV transmission in modern hospital-based settings [4]. The compelling requirement for a vascular access site, along with the extracorporeal circulation

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necessary to perform HD, adds to the risk of parenteral exposure to prevailing HCV infection within the unit. Nurse understaffing in units with high HCV prevalence may further increase the odds of HCV transmission since insufficient time to fully comply with disinfection requirements may facilitate cross-infection via blood-contaminated gloves and hands, dialysis equipment, dialyzer and blood line surfaces [4–9].

This study was designed to investigate any impact that nurse understaffing might have on the transmission of HCV in an HD unit.

Subjects and Methods

Study Population

In this retrospective analysis, records of 198 ESRD patients enrolled for long-term HD from August 2, 1995, to August 1, 2000, at King Fahad Hospital and Tertiary Care Center, Hofuf, Saudi Arabia, were reviewed. There were 107 males and 91 females. The mean age of the patients was 47.0 ± 17.5 years (range 15–84 years). Age, gender and HCV serostatus, units of blood transfused, length of time on HD (dialysis age) and the number of patients cared for by 1 HD nurse were collected.

The subjects were assigned to 1 of 3 groups of varying patient/nurse (P/N) ratios: group I, 2:1 ($n = 56$); group II, 3:1 ($n = 110$), or group III, 4:1 ($n = 32$). These ratios were affected by nurse turnover and patient comorbidities (ischemic heart disease, diabetes mellitus and congestive heart failure) that involved higher levels of nursing care during HD. Additionally, age, gender, nursing hours, patient-days, number of units of blood transfused and dialysis age, along with HCV seroprevalence and seroconversion rates, were noted in each of these groups and matched.

These ESRD patients were dialyzed 2 or 3 times per week for 4 h each time using disposable single-use, high-flux dialyzer membranes (polysulfone, Bellco, Mirandola, Italy; polyacrylonitrile Filtrat 10 AN 69, Hospal, Meyzieu, France) and blood lines. HCV-positive and -negative patients were dialyzed in a common area, while patients with HBV infection were strictly isolated as per Centers for Disease Control (CDC) guidelines [10]. Male and female patients were placed in separate rooms.

HD Nurse Staffing

HD staff nurses were assigned randomly, regardless of HCV serological status, with the same staff nurse taking care of HCV-positive and HCV-negative patients but with strict enforcement of universal infection control precautions. The P/N ratio was based on the number of dialysis nurses and patients. Technicians engaged solely to manage and repair the dialysis machines were not counted as nursing staff as they were not directly involved in the HD patients' care.

Infection Control Precautions

Strict adherence to universal precautions for infection control as recommended by the CDC was practiced routinely, regardless of HCV or HBV serological status [10, 11]. All staff members taking care of HD patients wore gowns, masks, gloves and protective eye wear while preparing, performing and terminating dialysis. Gloves

were changed after each patient manipulation, and hands were washed between each patient. Meticulous cleaning and disinfection of environmental surfaces at each dialysis station was done before all dialysis sessions, and wastes generated were disposed of in an incinerator, in accordance with Saudi Arabia regulations governing medical waste.

Disinfection of HD Machines

The HD machines (Hospal Integra™, Meyzieu, France), were disinfected after each patient (HCV positive or negative) with hot water and chemicals (Puristeril and sodium hypochlorite). Chemical disinfection, as per instructions of the manufacturers, involved using 0.1% peracetic acid (Puristeril® 340, Fresenius AG, Homburg, Germany) and running the machine at 85 °C for 35 min after each dialysis session. After the chemical disinfection, hot water, at 80–90 °C, was run at a high flow rate for 60 min. This procedure was performed at the end of the day on every machine in preparation for the next day's work, while disinfection of the dialysate circuit was performed with sodium hypochlorite (<0.3 ppm) after each individual session. External, disposable venous and arterial pressure transducer filters were also changed and discarded between each patient treatment after single use.

Detection of HCV Infection

Blood samples were collected from all patients on the date of their enrollment in the unit and subsequently every 3 months for analysis of HCV infection. The serum samples were stored at –20 °C until analysis for anti-HCV antibodies by a second-generation enzyme-linked immunosorbent assay (ELISA-2) using Murex version III kits (Murex Biotech Ltd., Dartford, UK) was done. All the anti-HCV-positive samples were confirmed by a recombinant immunoblot assay (Chiron-RIBA-HCV 3.0, Ortho Clinical Diagnostics, Raritan, N.J., USA). Seroconversion rates were calculated at the end of each year by recording the percentage of new cases per year.

In addition to patients, all personnel (renal physicians, staff nurses and HD technicians) were tested annually for anti-HCV/HBV and liver enzymes. Blood and blood products used for transfusion were acquired from voluntary donors and screened for anti-HCV with ELISA-2.

Statistical Analyses

The statistical package for social sciences SPSS version 10.1 (SPSS, Chicago, Ill., USA) was used for data processing. The value $p < 0.05$ (two-sided) was used as a cutoff level for statistical significance. The χ^2 test was used to assess the difference between two proportions of anti-HCV-positive patient groups with different N/P ratios. The Student *t* test was used to compare between the means of two quantitative variables. Mantel-Haenszel odds ratios and 95% confidence intervals were used to investigate the association between the seroconversion rates and selected risk factors. Significantly associated variables with the risk of acquiring HCV infection in the univariate analysis were excluded in a multivariate logistic regression model.

Since the duration of follow-up was not uniform, the prognostic significance of being dialyzed with different P/N ratios was tested by cumulative survival analysis at the main time points [HCV serology at the beginning of HD (the study entry) and the time of becoming anti-HCV positive]. The cumulative survival curves were obtained by the Kaplan-Meier survival method. The equality of the survival curves was assessed by the Cox proportional hazard test.

Table 1. Determinants of HCV seroconversion in 198 HD patients

Variables	Anti-HCV serology		Mean sero-conversions/year	p value
	positive	negative		
Patients	86/198 (43.4)	112/198 (56.6)	17.2 (8.6)	
Mean age $\pm$ SD, years	65.0 $\pm$ 9.2	49.0 $\pm$ 5.8		0.028
Gender				
Male	54/86 (62.8)	53/112 (47.3)	10.8 (10.09)	0.043
Female	32/86 (37.2)	59/112 (52.6)	6.4 (7.03)	
Mean dialysis age $\pm$ SD, months	50.0 $\pm$ 8.6	29.0 $\pm$ 5.9		0.002
Mean number $\pm$ SD of units of blood transfused	7.2 $\pm$ 2.5	6.8 $\pm$ 3.7		NS
P/N ratio				
Group I (2:1)	15/56 (26.8)	41/56 (73.2)	3.0 (5.35)	reference group ¹
Group II (3:1)	48/110 (43.8)	62/110 (54.4)	9.6 (8.7)	<0.05
Group III (4:1)	23/32 (71.8)	9/32 (14.4)	4.6 (14.4)	<0.001

Results in parentheses indicate percentages. Dialysis age = Time span since the initiation of the HD treatment; SD = standard deviation; NS = not significant; P/N = patient-to-nurse ratio.

¹ Odds ratio = 1.

Results

All ESRD patients had been on HD for a mean of 39.5 $\pm$ 7.25 months (range 4–102 months).

Factors affecting HCV positivity are listed in table 1. Of 198 ESRD patients, 86 (43.4%), including 54 males and 32 females, were anti-HCV positive. They were older (65.0 $\pm$ 9.2 years) than anti-HCV-negative patients (49.0 $\pm$ 5.8 years). The difference in age was statistically significant ($p < 0.03$). More males (62.8%, 54/86) than females (37.2%, 32/86) were HCV positive, and the difference was statistically significant ($p < 0.043$). The number of units of blood transfused to HCV-positive and -negative patients was the same: 7.2 $\pm$ 2.5 and 6.8 $\pm$ 3.7 units, respectively.

Anti-HCV-positive patients had a higher dialysis age (50.0 $\pm$ 8.6 months) than anti-HCV-negative patients (29.0 $\pm$ 5.9 months). The difference was statistically significant ($p < 0.02$). The overall HCV seroconversion rate was 8.6% per year (table 1). The mean HCV seroprevalence and seroconversion rates for the 3 groups and the yearly seroconversion rates are shown in figures 1 and 2, respectively. Among different patient groups, group I (P/N ratio 2:1) had the lowest HCV prevalence (26.8%, 15/56) and yearly seroconversion rate (5.3%), at a mean dialysis age of 68.0 $\pm$ 9.2 months. Higher HCV prevalence (43.6 %, 48/110) and yearly seroconversion (8.7%) rates were found in group II (P/N ratio 3:1), with a mean dialysis age of 47.0 $\pm$ 9.4 months. Group III (P/N ratio 4:1) had the highest HCV prevalence (71.8%, 23/32) and

Fig. 1. Mean HCV seroprevalence and mean seroconversion rates among various groups with different P/N ratios.

seroconversions (14.4%) per year, at a mean dialysis age of 35.0 $\pm$ 2.4 months. As should be expected, group I had the highest number of nursing hours per patient-day (48) while groups II and III had 23.6 and 24 h, respectively.

The other factors analyzed, mean age, male/female ratio and units of blood transfused, were comparable among all the 3 groups (table 2).

According to the criteria expressed in Patients and Methods, 2 of the 4 variables included in the multiple logistic regression equation (dialysis age and staffing levels)

Fig. 2. Annual HCV seroconversion rates among various groups with different P/N ratios during the study period (1995–2000).

Fig. 3. Kaplan-Meier cumulative survival curves demonstrating the probability of HCV seroconversions in various patient groups being dialyzed with different staffing levels. HR = Hazard ratio; 95% CI = 95% confidence interval.

Table 2. Patient characteristics and determinants of HCV seroconversion among various patient groups dialyzed with different P/N ratios (1995–2000)

Variables	Group I (P/N ratio 2:1)	Group II (P/N ratio 3:1)	Group III (P/N ratio 4:1)
Patients	56/198 (28.3)	110/198 (55.5)	32/198 (16.2)
Mean age $\pm$ SD, years	63.8 $\pm$ 5.8	59.2 $\pm$ 8.2	50.0 $\pm$ 9
Gender			
Male	36/56 (64.3)	54/110 (49.1)	17/32 (53.2)
Female	20/56 (35.7)	56/110 (50.9)	15/32 (46.8)
Nursing hours	322,560	311,040	92,160
Patient-days	6,720	13,200	3,840
Nursing hours per patient-day	48	23.56	24
Mean number $\pm$ SD of units of blood transfused	7.5 $\pm$ 2.5	6.9 $\pm$ 2.6	7.2 $\pm$ 2.4
Mean dialysis age $\pm$ SD, months	68.0 $\pm$ 9.2	47.0 $\pm$ 9.4	35 $\pm$ 7.3
HCV serology			
Positive	15/56 (26.8)	48/110 (43.8)	23/32 (71.8)
Negative	41/56 (73.2)	62/110 (56.4)	9/32 (28.2)
Mean seroconversions/year	3 (5.35)	9.6 (8.7)	4.6 (14.4)
OR, 95% CI, p value	reference group ¹	2.11, 0.99–4.50, <0.05	6.98, 2.39–20.93, <0.001

Figures in parentheses indicate percentages. Dialysis age = Time span since the initiation of the HD treatment; OR = odds ratio; 95% CI = 95% confidence interval; SD = standard deviation; nursing hours = total nursing hours during study period; patient-days = total patient hours on HD during study period divided by 24 h.

¹ OR = 1.

remained in the multiple logistic regression model. The other 2 variables (age and male gender) did not reach statistical significance and were excluded. The 2 factors that showed a statistically significant association in univariate analysis maintained their effect after adjustment of remaining potential confounders. Kaplan-Meier survival curves were drawn showing a relationship between the HCV seroconversions among patient groups with different staffing ratios (2:1, 3:1 and 4:1) and the follow-up time period expressed in months.

Survival data with a Cox regression model and estimation of hazard ratios for the 3 patient groups are shown in figure 3.

No HD personnel tested positive for HCV/HBV at any stage in the study.

Discussion

The HCV seroprevalence of 43.4% observed in this study is comparable to the 43.2% reported in the Al-Hasa region of Saudi Arabia [12]. However, it is much lower than the 68% reported in a multicenter epidemiological study also carried out on HD patients in Saudi Arabia [1]. The overall seroconversion rate of 8.6 per year observed

Table 3. Determinants of the HCV seroconversion by multivariate analysis (1995–2000)

Determinants	MLR OR	95% CI
Dialysis age	4.3	1.383–15.541
Staffing levels		
Group I (P/N 2:1)	1	reference group ¹
Group II (P/N 3:1)	5.9	1.863–17.836
Group III (P/N 4:1)	9.8	2.663–32.924

Dialysis age = Time span (months) since the initiation of the HD treatment; MLR OR (multiple logistic regression odds ratios) and 95% CI (95% confidence Intervals) were adjusted for the variables having $p < 0.05$ and/or odds ratios ≥ 2 (i.e. age, male gender, dialysis age, staffing levels) at univariate analysis of anti-HCV-positive patients among various patient groups on HD with different staffing levels, as shown in table 1.

¹ Odds ratio = 1.

at this tertiary care center is comparable to those of 7–9% reported from other centers of Saudi Arabia and elsewhere [1, 6]. However, annual seroconversion rates of $>5\%$ reported in high-prevalence HD units ($>20\%$ prevalence rates) remain a cause for concern [6].

One plausible explanation for the high seroconversion rate is nurse understaffing, as manifested in the number of patients per HD group. As evidenced in this study, the highest seroconversion rate and HCV prevalence were observed in group III with the highest P/N ratio and consequently low nursing hours per patient-day (24 h). These findings are similar to those reported previously [16–18], which claimed that nurse understaffing increased the risk of nosocomial infection. However, the significant difference in the HCV prevalence and seroconversion rates between group II (P/N 3:1) and group III (P/N 4:1) in spite of the comparable total nursing hours per patient-day (23.56 vs. 24 h) points to the fact that the P/N ratio is definitely a much better indicator of the staffing levels in the HD units than the total nursing hours per patient-day.

In spite of a policy requiring strict adherence to CDC infection control regulations [11], it is possible – also in cases of understaffing, especially when emergencies arise – that there may be some laxity in adherence due to time constraints or exhaustion. As a result, patients are at increased risk for cross-contamination and consequent nosocomial infection. For example, one study reported failure to change gloves between patients while performing HD treatments, especially during emergency situations [7], and another found HCV-RNA in hand washings from nurses dialyzing HCV-positive and -negative patients [9]. Molecular virological studies have also clearly implicated nosocomial transmission of HCV within high-risk HD settings [5–9]. Certainly, cross-infection via a nosocomial pathway from already infected patients could occur due to contamination of vascular access sites that necessitate regular punctures and cannulations to carry out HD.

Dialysis age (length of time on HD) has been considered a powerful predictor of HCV infection risk: the chances of acquiring HCV infection are much higher after a decade of HD, with a reported predictable risk of 10% per year [14]. We found a significant association between dialysis age and anti-HCV positivity, consistent with previous findings [14, 15]. Patients with a dialysis age of 50.0 ± 8.6 months carried a significantly higher risk ($p < 0.002$) of acquiring HCV infection than those with a dialysis age of 29.0 ± 5.9 months. Shared dialysis equipment and dialyzer reuse have been implicated as factors in patient-to-patient nosocomial HCV transmission since disruption of the membrane integrity while processing the dialyzers could possibly permit the passage of virus into the blood compartment. In addition, lapses in infection control measures, more likely to occur over time, may

result in patient-to patient transmission via blood-contaminated machines and the gloves/hands of nursing staff [1, 5–9].

However, significantly higher HCV prevalence and seroconversion rates observed in the groups with comparatively lower mean dialysis ages (group II, 47 months, $p < 0.05$, and group III, 35 months, $p < 0.001$) than group I (68 months, $p < 0.001$) indeed suggest that the acquisition of HCV infection occurs significantly earlier (at a lower dialysis age) among the patients in the groups with higher P/N ratios than in those with a relatively lower P/N ratio, during the course of long-term dialysis treatment (table 1).

When the odds of HCV seroconversions developing over a 5-year follow-up period were estimated using Kaplan-Meier cumulative survival curves (fig. 3), group I, with the lowest P/N ratio (2:1), had the lowest probability of seroconversions. Although the probability of HCV seroconversions decreased over time among the 3 patient groups, higher levels of HCV seroconversions were obtained for both groups II and III, with hazard ratios of 1.639 ($p < 0.006$) and 2.389 ($p < 0.0001$), respectively.

Repeated blood transfusions are no longer considered a major risk factor for the transmission of HCV. Due to routine HCV screening by highly sensitive tests (ELISA anti-HCV) for blood donors, the risk of posttransfusion HCV infection is currently less than 1/100,000 units [13]. As the numbers of units of blood transfused between the anti-HCV-positive and anti-HCV-negative groups in this study were comparable (7.2 ± 2.5 vs. 6.8 ± 3.7 units) and the prevalence of anti-HCV antibody among blood donors in this region is only 0.67% [12] – significantly lower than the 43.4% overall HCV prevalence in this study – transmission of HCV infection within the dialysis unit through means other than blood transfusion is highly probable.

The higher HCV prevalence and annual seroconversion rates seen in the groups with greater numbers of patients per nurse, groups II and III, suggest a breakdown in infection control measures. While strict isolation of HCV-positive patients may be indicated, improving nursing staff levels is likely to play a major role in reducing HCV seroconversion rates, particularly in those HD units where HCV is prevalent [19, 20]. Further studies to clearly define optimal P/N ratios for these HD units would also be of great significance.

Conclusion

The findings that the patients in the groups with the relatively higher P/N ratio had the significantly higher HCV prevalence and seroconversion rates per year and

low nursing hours per patient-day indicate that understaffing is likely to play a major role in the transmission of HCV in HD units. We therefore suggest that improved staffing will be helpful in reducing the HCV transmission in such dialysis units.

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