Clin Exp Nephrol
DOI 10.1007/s10157-013-0824-6

ORIGINAL ARTICLE

Characteristics and 3-year mortality and infection rates among incident hemodialysis patients with a permanent catheter undergoing a first vascular access conversion

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Received: 1 November 2012 / Accepted: 24 May 2013

Abstract
Background Although vascular access conversions to arteriovenous fistula (AVF)/arteriovenous graft (AVG) in incident and maintenance hemodialysis (HD) patients are reported to be associated with lower mortality and infection risk, it is unclear whether these effects are limited to the first year. The aims of this historical cohort study were to investigate patient characteristics of vascular access conversion and the impact of vascular access conversion on 1- and 3-year mortality and infection rates in incident HD patients with a permanent catheter to initiate HD.
Methods Our study included 868 incident patients who underwent HD for at least 3 months and who, between January 1, 2004 and December 31, 2006, received a permanent catheter within 3 days of starting HD. The effects of vascular access conversion on rates of infection and mortality during the subsequent 3 years were assessed using claims data from the National Health Insurance Program in Taiwan.
Results Factors associated with lower 1- and 3-year mortality and infection rates were a first vascular access converted to AVF or AVG, female gender, age <65 years, and the presence of a lower Romano–Charlson comorbidity index score ($P < 0.05$). Patients who received an AVF/AVG at hospitals which perform a high number of vascular access procedures annually had lower 3-year infection rates.
Conclusion The lower mortality and infection rates also extended throughout the 3-year period in incident patients starting HD with a permanent catheter to receiving vascular access conversion to AVF (Hazard ratio [HR] 0.47, 95 % CI 0.32–0.67, $P < 0.0001$) and AVG (HR 0.51, 95 % CI 0.27–0.99, $P < 0.05$).

Keywords Arteriovenous fistula · Arteriovenous graft · Hemodialysis · Infection · Mortality · Vascular access conversion

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Introduction

Although catheter use is linked to higher rates of infection and mortality and could compromise dialysis adequacy [1–6], the ease of approach, the improved plastic, the design in the catheter and the fact that there is no 'lag time' for start of dialysis may play an important role in the increasing use of catheters as vascular access for the initiation of hemodialysis (HD); even physicians and their patients who are reluctant to receive an arteriovenous fistula (AVF) or arteriovenous graft (AVG) before starting HD, can see the advantages [7–12]. Vascular access conversions to AVF/AVG in incident and maintenance HD patients are also reported to be associated with lower 1-year mortality risk and hospitalization in Western countries [13–15]; however, it is unclear whether these effects are limited to the first year. Therefore, an investigation into the 1-year (short term) and 3-year (long term) effects of vascular access conversion on rates of infection and mortality in incident HD patients who begin HD with a permanent catheter would be beneficial. It is also worth investigating factors relating to vascular access conversion in other countries with different insurance systems to enable surgeons and patients to make an appropriate plan for vascular access conversion. Therefore, the aims of this historical cohort study were to investigate the patient characteristics of vascular access conversion and the impact of vascular access conversion on 1- and 3-year infection and mortality rates of incident HD patients who initiate HD with a permanent catheter by using claim data from the National Health Insurance (NHI) program in Taiwan.

Materials and methods

Healthcare system and data source

As in many other industrialized nations, the demand in Taiwan for universal healthcare led to the creation of a NHI program, which began on March 1, 1995. All medical institutions must submit standard claims documents for medical expenses on a computerized form that lists the outpatient clinic, the admission and discharge dates, the patient's identification number, sex, date of birth and diagnosis codes for the admission, which are taken from the International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM). These codes, which consist of a principal and up to four secondary diagnoses for inpatient care and two secondary diagnoses for outpatient care, facilitate the analysis of health care patterns. The database also includes codes for treatment procedures and materials such as AVF (code 69032C) and AVG (code 69032C plus the material codes for the graft), permanent catheters (code 47059B, 47061B) and temporary catheters (code 69006C, 69007B). The Romano–Charlson comorbidity index (CCI) was assessed using hospital claims and outpatient diagnosis codes during the year preceding dialysis.

At the end of 2000 and 2008, Taiwan's NHI program had covered 21 and 23 million people, respectively, accounting for 96.2 and 99 % of the population eligible to receive program benefits [16]. Because the NHI program is available to all residents regardless of age or income, its scope is extensive, thus making it possible for detailed analyses of particular patterns in health care to be conducted.

Definition and patterns of vascular access conversion

The billing data for AVF, AVG, permanent catheter and temporary catheter is defined as 'vascular access conversion', i.e., as a conversion from a permanent catheter used at start of HD to an AVF, AVG, temporary catheter, or secondary permanent catheter (a permanent catheter implanted after failure of the initial permanent catheter) within the first 120 days of HD.

Patients were assigned to 1 of 4 groups depending on their access conversion status. Group 1 consisted of incident patients with a permanent catheter for HD who did not have vascular access conversion during the first 120 days. Groups 2 and 3 consisted of patients who started HD with a permanent catheter, and whose first conversion during the first 120 days of HD was to an AVF (group 2) or AVG (group 3). Group 4 consisted of patients who started HD with a permanent catheter, and whose first conversion during the first 120 days of HD was to a secondary permanent catheter or temporary catheter.

Patients

In this study, we investigated the patient characteristics of vascular access conversion and the impact of vascular access conversion on 1-year and 3-year mortality and infection rates on incident HD patients with a permanent catheter to initiate HD. Therefore, 22,844 patients who started HD with an AVF or AVG were excluded from the 23,907 incident patients who received HD between January 1, 2004 and December 31, 2006. This study enrolled incident patients $\geq$18 years of age who, between January 1, 2004 and December 31, 2006, received a permanent catheter within 3 days before their first dialysis. All patients had received regular HD for at least 3 months. To avoid immortal person-time [17, 18] in the different groups of patients we had to define the beginning of the time at risk for death and infection. In this study, 80 % of incident patients received vascular access conversion within the first 120 days. Therefore, vascular access conversion within the first 120 days was chosen as the cut-off point for evaluating infection and mortality. Patients who had vascular access conversion more than once or died within the first 120 days were excluded from this study. For the analysis of infection-free days, patients who experienced infection within the first 120 days were also excluded. Thus, the beginning of the time at risk for mortality and infection in the different groups was similar. Finally, a total of 868 and 644 incident patients with a permanent catheter to initiate dialysis were recruited for analysis of mortality and infection-free days, respectively (Fig. 1). An encrypted

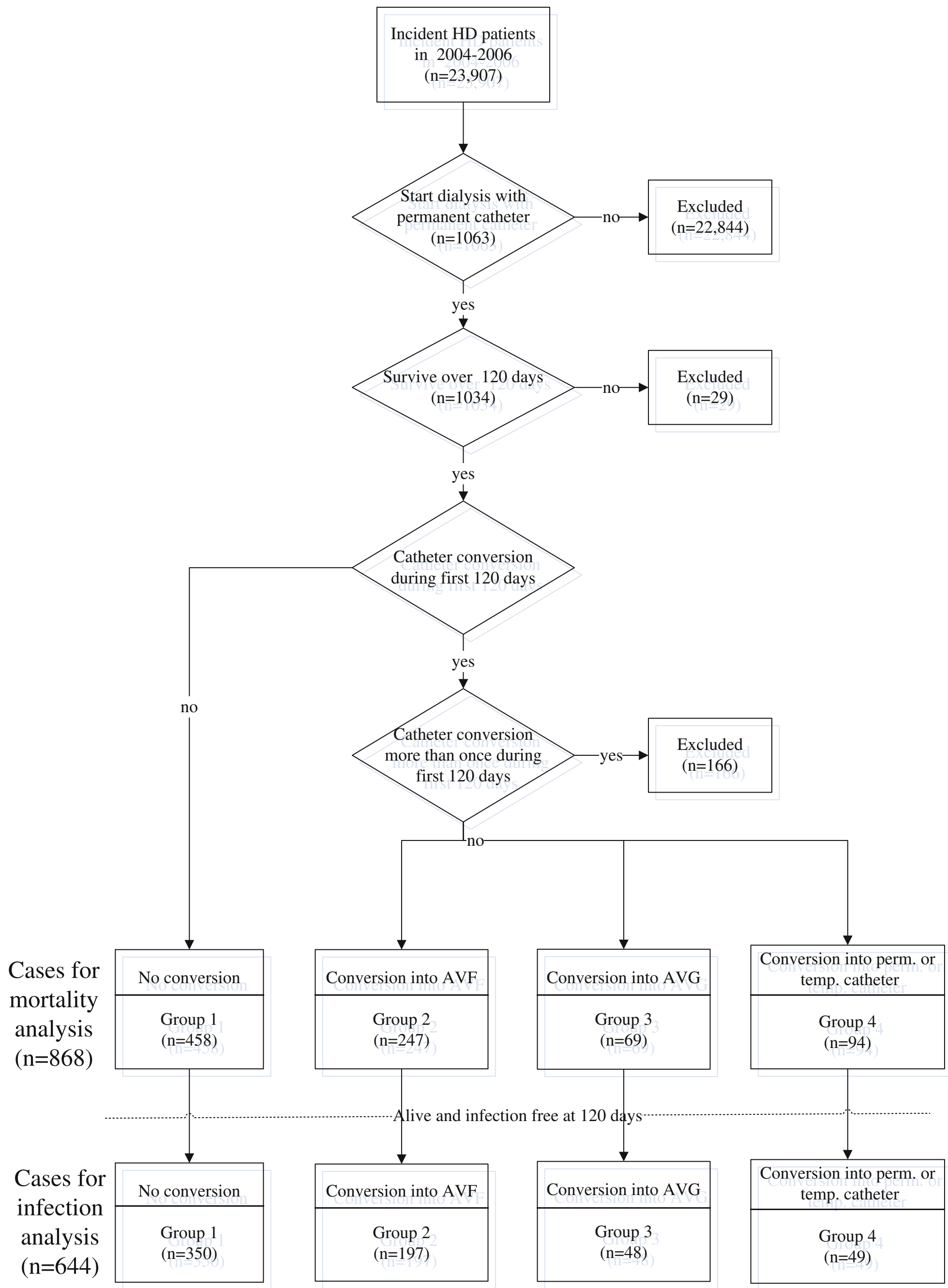

Fig. 1 Chart of subject selection for this study. From the total subjects in the data set ($n = 23{,}907$), the patients ($n = 22{,}844$) who started hemodialysis with AVF or AVG were excluded. We selected incident patients started hemodialysis with a permanent catheter. The incident patients were assigned to different groups according to survival and infection-free over 120 days, the first time of vascular access conversion and the pattern of vascular access conversion. Finally, 868 and 644 patients were recruited for mortality and infection analysis, respectively. Group 1, the incident patients with permanent catheter for HD who did not have vascular access conversion during the first 120 days; group 2, patients with a permanent catheter who had the first vascular access conversion to AVF for HD during the first 120 days; group 3, patients with a permanent catheter who had the first vascular access conversion to AVG for HD during the first 120 days; group 4, patients with a permanent catheter who had the first vascular access conversion to a secondary permanent catheter (permanent catheter created following failure of initial permanent catheter was defined secondary permanent catheter) or to a temporary catheter for HD during the first 120 days

unique identification number was used to link information for each individual patient to the database of death certificates and national household registration, managed by the Department of Health and the Government of Taiwan, to identify the patient's date of death, education and marital status.

Since the subcutaneous tunnel and cuff ensure stabilization of the position of permanent catheters (tunneled cuffed catheters) while fibroblasts growing into the cuff limit the migration of microorganisms on its external surface and reduce the risk of infections, permanent catheters are preferred for dialyses >3 weeks [19]. Therefore, a permanent catheter rather than a temporary catheter (non-tunneled uncuffed catheter) is usually used for incident patients without vascular access for the initiation of HD in Taiwan. Referral to a nephrologist was defined as the time at which a nephrologist's care began on the NHI billing data. Patients who had been under a nephrologist's care for at least 4 months before start of HD were defined as early referral [7]. Early referral may indicate that the patient received more education and advice on dialysis and vascular access.

Dependent variable

To avoid immortal person-time, survival and infection-free days were defined as the time from the 121st day after start of HD to the time of death or to infection during the study period, respectively. Patients with codes ICD-9-CM 996.62 (infection and inflammatory reaction due to vascular device, implant and graft) or 038.X (septicemia) were defined as infection in the study. One-year survival was calculated from the 121st day after start of HD until either HD day 485 (censor), the second vascular access conversion (censor), the end of year 2007 (censor), or death (event), whichever was earliest. Three-year survival was calculated from the 121st day after start of HD until either HD day 1215 (censor), the second vascular access conversion (censor), the end of year 2007 (censor), or death (event), whichever was earliest. The number of 1-year infection-free days was calculated from the 121st day after start of HD until either HD day 485 (censor), death (censor), the second vascular access conversion (censor), the end of year 2007 (censor), or infection (event), whichever was earliest. The number of 3-year infection-free days was calculated from the 121st day after start of HD until either HD day 1215 (censor), death (censor), the second vascular access conversion (censor), the end of year 2007 (censor), or infection (event), whichever was earliest. Patients who underwent renal transplantation or switched to peritoneal dialysis after the first 120 days of HD were censored. Infection including sepsis was identified based on the diagnostic code (ICD-9-CM 996.62, 996.1, 038.X) at a subsequent admission.

Covariates

Patient demographic and clinical information identified from the primary and secondary diagnosis codes in the claims data included sex, age (18–64, 65–74, ≥75 years), education status (≤6, ≥7 years), marital status (without or with a spouse), place of residence (city or county), early referral to nephrologists (no or yes), CCI in the year before start of HD (using the Romano–CCI method, 15 potentially important comorbidities were found, excluding renal disease; no AIDS was found in the present study), diabetes, hospital ownership (private or public), and annual number of vascular access procedures at a particular hospital (where the hospital performed an annual number of vascular access procedures <median (105 cases/year) or ≥median). A higher Romano–CCI scores indicate a higher number of comorbidities [20, 21]. The CCI was assessed using hospital claims and outpatient diagnosis codes during the year preceding dialysis.

Statistical analysis

The SAS 9.1.3 statistical software for Windows (SAS Institute Inc., Cary, NC, USA) was used for data management and analysis. The SPSS 15.0 statistical software for Windows (SPSS Inc.) was used to generate survival and infection-free curves for each vascular access conversion group using the Kaplan−Meier method. Basic descriptive analysis for continuous variables (mean ± SD, and median) and for categorical variables (frequencies and percentages) was used to characterize patients by the pattern of vascular access conversion. Associations between variables and patterns of vascular access conversion were examined using the Chi-squared test. Kaplan–Meier survival analysis was used to generate survival curve. A two-tailed $P < 0.05$ was considered statistically significant. Cox regression was used to assess the influence on infection or death of age, sex, education, marital status, urbanization, early referral to nephrologists, CCI, diabetes, hospital ownership, annual number of vascular access procedures at a particular hospital and patterns of vascular access conversion. This study also added the interaction between referral and group of vascular access conversion to the Cox regression model.

Results

Basic characteristics of patients with different patterns of vascular access conversions

Overall, 507 of 868 (58.4 %) patients were female; 55.4 % were diabetic; 40.6 % were 18–64 years of age, 27.5 % were 65–74 years of age, and 31.9 % were >75 years of age (Table 1).

The distribution of age, education, marital status, CCI score, diabetes and infection during the first 120 days of HD were different among vascular access conversion groups ($P < 0.05$). More patients in groups 1 and 4 were >75 years of

Table 1 Patient characteristics and clinical manifestations of the incident patients with different patterns of vascular access conversion ($n = 868$)

	Total ($n = 868$)	Group 1 ($n = 458$)	Group 2 ($n = 247$)	Group 3 ($n = 69$)	Group 4 ($n = 94$)	P value
Total (%)	100	52.8	28.5	8.0	10.8	
Sex						
Female	58.4	58.5	55.9	71.0	55.3	0.1363
Male	41.6	41.5	44.1	29.0	44.7	
Age group (years)						
18–64	40.6	35.2	55.5	49.3	21.3	<0.0001
65–74	27.5	27.1	25.1	27.5	36.2	
>75	31.9	37.8	19.4	23.2	42.6	
Education (years)						
≤6	68.5	66.2	65.2	82.6	78.7	0.0039
≥7	31.5	33.8	34.8	17.4	21.3	
Marital status						
Without spouse	35.8	40.6	27.1	27.5	41.5	0.0011
With spouse	64.2	59.4	72.9	72.5	58.5	
Urbanization						
City	58.3	58.7	59.5	52.2	57.4	0.7343
County	41.7	41.3	40.5	47.8	42.6	
Early referral to nephrologists						
No	70.7	70.5	67.2	69.6	81.9	0.0653
Yes	29.3	29.5	32.8	30.4	18.1	
CCI						
≤1	33.3	32.1	39.3	33.3	23.4	0.003
2	21.1	19.2	24.7	26.1	17.0	
≥3	45.6	48.7	36.0	40.6	59.6	
Diabetes	55.4	53.7	51.0	66.7	67.0	0.011
Hospital ownership						
Private	72.4	72.3	76.5	68.1	64.9	0.1462
Public	27.6	27.7	23.5	31.9	35.1	
Annual surgical number of vascular access at hospital (105 cases/per year)						
<Median	49.9	46.1	55.1	56.5	50.0	0.0885
≥Median	50.1	53.9	44.9	43.5	50.0	
Infection within first 120 days of hemodialysis						
Yes	25.8	23.6	20.2	30.4	47.9	<0.0001
No	74.2	76.4	79.8	69.6	52.1	

Group 1, incident patients with a permanent catheter for HD who did not have vascular access conversion during the first 120 days; group 2, patients with a permanent catheter who had the first vascular access conversion to AVF for HD during the first 120 days; group 3, patients with a permanent catheter who had the first vascular access conversion to AVG for HD during the first 120 days; group 4, patients with a permanent catheter who had the first vascular access conversion to a secondary permanent catheter (permanent catheter created following failure of initial permanent catheter was defined secondary permanent catheter) or to a temporary catheter for HD during the first 120 days; *CCI* Romano–Charlson comorbidity index. Chi-squared was conducted to test the difference among different pattern of vascular access conversion. A P value <0.05 indicates statistical significance

age, lived without a spouse, and had a CCI score of ≥3. More patients in group 4 experienced infections during the first 120 days of HD. Approximately ≥70 % patients in each vascular access conversion group were late referrals (Table 1).

Infection and mortality rates by the pattern of vascular access conversion

Infection including sepsis occurred in 31.3 %, and mortality in 26.0 % of incident patients who used a permanent catheter to initiate HD in the first year. The access conversion groups showed significant differences in their rates of infection and mortality in the first year ($P < 0.0001$). During the first year, the mortality rates in groups 2 (11.0 %) and 3 (10.9 %) were also considerably lower than in groups 1 (33.7 %) and 4 (38.1 %) (Table 2). The infection rates in groups 2 (16.2 %) and 3 (21.1 %) were considerably lower than in groups 1 (38.7 %) and 4 (50.7 %) (Table 2). These trends were also seen in the third year ($P < 0.0001$) (Fig. 2).

Years of survival and infection-free days by the pattern of vascular access conversion

In the 3-year follow-up, the mean survival was 759.8 ± 16.5 days and the mean infection-free period was

Table 2 Infection and mortality in the first year by the patterns of vascular access conversion

	Death ($n = 868$)			Infection ($n = 644$)		
	Rate (%)	Survival days		Rate (%)	Infection-free days	
		Mean	SD		Mean	SD
Group 1	33.7	256.6	129.0	38.7	223.8	137.4
Group 2	11.0	288.9	121.0	16.2	274.8	127.5
Group 3	10.9	262.2	128.7	21.1	242.0	132.2
Group 4	38.2	121.8	123.8	50.7	123.6	117.0
Total	26.0	251.6	134.6	31.3	233.1	137.8

Group 1, incident patients with a permanent catheter for HD who did not have vascular access conversion during the first 120 days; group 2, patients with a permanent catheter who had the first vascular access conversion to AVF for HD during the first 120 days; group 3, patients with a permanent catheter who had the first vascular access conversion to AVG for HD during the first 120 days; group 4, patients with a permanent catheter who had the first vascular access conversion to a secondary permanent catheter (permanent catheter created following failure of initial permanent catheter was defined secondary permanent catheter) or to a temporary catheter for HD during the first 120 days. To avoid immortal person-time, the 121st day from the start of HD was counted as the first day for the analysis of the first-year infection and mortality rates

712.4 ± 120.3 days overall. The mean survival and infection-free periods were much longer in group 2 (948.8 ± 22.9 and 867.6 ± 30.5 days, respectively) than in the other groups (668.6 ± 22.6 and 631.8 ± 27.8 days in group 1, 906.8 ± 49.8 and 843.9 ± 68.7 days in group 3, 537.6 ± 75.4 and 319.4 ± 51.7 days in group 4, respectively) (Fig. 2).

Significant risk factors associated with mortality

Bivariate and multivariate Cox regression analysis both showed that male sex, age >64 years, and a CCI score of ≥2 were all independent risk factors for 1- and 3-year mortality ($P < 0.05$) (Table 3). Lower 1- and 3-year mortality rates were associated with patients in groups 2 and 3. The lower 1- and 3-year mortality effects in group 2 ($P < 0.001$) were better than group 3 ($P < 0.05$). Early referral to nephrologists and diabetes were not significantly associated with 1- and 3-year mortality in multivariate analysis (Table 3).

Significant risk factors associated with infection

The bivariate Cox regression analysis of variables significantly associated with 1- and 3-year infection showed that the risk was significantly increased in patients who belonged to group 4 (hazard ratio [HR] was 1.81 and 1.87, respectively; $P < 0.05$), who were >64 years of age, who had a CCI score of ≥3, who had diabetes and who received HD at private hospitals ($P < 0.05$) (Table 4). The risk was significantly lower for patients in groups 2 and 3, for those who had >6 years education, and who lived with a spouse

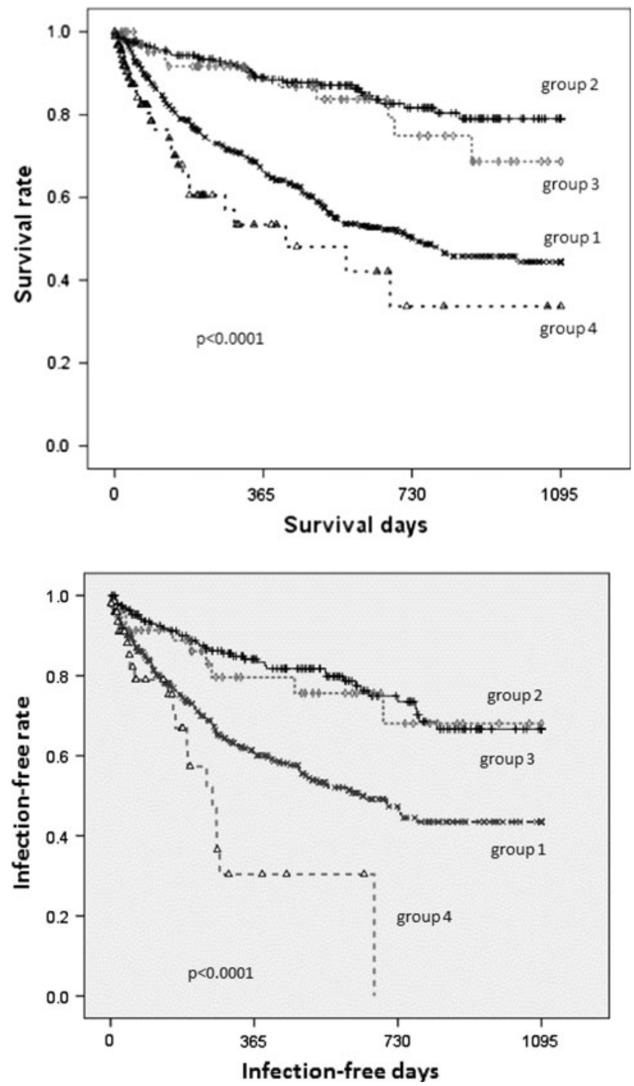

Fig. 2 The 3-year survival and infection-free rates of incident patients with different patterns of vascular access conversion. The upper panel is the 3-year survival curve by patterns of vascular access conversion. The lower panel is the 3-year infection-free days by patterns of vascular access conversion. Group 1, the incident patients with a permanent catheter for HD who did not have vascular access conversion during the first 120 days; group 2, patients with a permanent catheter who had the first vascular access conversion to AVF for HD during the first 120 days; group 3, patients with a permanent catheter who had the first vascular access conversion to AVG for HD during the first 120 days; group 4, patients with a permanent catheter have the first vascular access conversion to a secondary permanent catheter (permanent catheter created following failure of initial permanent catheter was defined secondary permanent catheter) or to a temporary catheter for HD during the first 120 days. To avoid immortal person-time, the 121st day from the start of HD was counted as the first day for the analysis of the 3-year mortality and infection rate

Table 3 Variables included in the Cox regression model to analyze the risk factors of mortality

	Cox regression for 1-year survival days ($n = 868$)						Cox regression for 3-year survival days ($n = 868$)					
	Bivariate analysis			Multivariate analysis			Bivariate analysis			Multivariate analysis		
	HR	95 % CI	*P*	HR	95 % CI	*P*	HR	95 % CI	*P*	HR	95 % CI	*P*
Patient characteristics												
Vascular access conversion (base: group 1)												
Group 2	0.28	0.18–0.44	<0.0001	0.37	0.24–0.58	<0.0001	0.28	0.19–0.4	<0.0001	0.36	0.24–0.52	<0.0001
Group 3	0.29	0.13–0.64	0.0026	0.39	0.17–0.88	0.0228	0.36	0.2–0.67	0.0011	0.47	0.25–0.87	0.0157
Group 4	1.74	1.13–2.66	0.0118	1.45	0.93–2.26	0.0985	1.66	1.11–2.48	0.0132	1.37	0.91–2.07	0.1341
Sex (base: female)	1.63	1.23–2.17	0.0007	1.81	1.33–2.47	0.0002	1.54	1.21–1.96	0.0005	1.79	1.37–2.33	<0.0001
Age group (base: 18–64 years) (years)												
65–74	2.97	1.95–4.5	<0.0001	2.28	1.48–3.52	0.0002	3.07	2.18–4.33	<0.0001	2.30	1.62–3.28	<0.0001
>75	4.4	2.99–6.47	<0.0001	3.30	2.16–5.03	<0.0001	4.08	2.95–5.64	<0.0001	2.90	2.04–4.13	<0.0001
Education (base: ≤6 years) (years)												
≥7	0.71	0.52–0.98	0.0361	0.93	0.65–1.32	0.6821	0.68	0.52–0.89	0.0057	0.88	0.65–1.19	0.4125
Marital status (base: without spouse)	0.78	0.59–1.04	0.0955	0.91	0.67–1.25	0.5686	0.73	0.57–0.94	0.013	0.82	0.63–1.08	0.1505
Urbanization (base: city)	1.21	0.91–1.6	0.1989	1.13	0.84–1.51	0.4347	1.12	0.88–1.43	0.3573	1.03	0.80–1.33	0.8219
Early referral to nephrologists (base: no)	0.76	0.55–1.06	0.1028	0.84	0.60–1.17	0.2927	0.72	0.55–0.96	0.0251	0.79	0.59–1.05	0.1083
CCI (base: ≤1)												
2	1.83	1.17–2.86	0.008	1.99	1.23–3.21	0.0048	2	1.37–2.91	0.0003	2.05	1.37–3.09	0.0006
≥3	2.77	1.91–4.02	<0.0001	2.89	1.79–4.66	<0.0001	3.03	2.2–4.16	<0.0001	3.00	1.96–4.58	<0.0001
Diabetes (base: 0)	1.34	1.01–1.79	0.0456	0.75	0.51–1.09	0.1286	1.513	1.179–1.943	0.0011	0.81	0.58–1.13	0.209
Hospital ownership (base: private)	1.14	0.84–1.56	0.411	0.91	0.65–1.26	0.5518	1.22	0.94–1.59	0.1411	0.93	0.71–1.24	0.6268
Annual number of vascular access procedures at hospital (base: <median, 105 cases/year)	1.1	0.83–1.46	0.5243	1.17	0.87–1.56	0.3047	0.92	0.72–1.17	0.4981	0.99	0.77–1.27	0.9264

Group 1, incident patients with a permanent catheter for HD who did not have vascular access conversion during the first 120 days; group 2, patients with a permanent catheter who had the first vascular access conversion to AVF for HD during the first 120 days; group 3, patients with a permanent catheter who had the first vascular access conversion to AVG for HD during the first 120 days; group 4, patients with a permanent catheter who had the first vascular access conversion to a secondary permanent catheter (permanent catheter created following failure of initial permanent catheter was defined secondary permanent catheter) or to a temporary catheter for HD during the first 120 days

HR hazard ratio, *CI* confidence interval, *CCI* Romano–Charlson comorbidity index

($P < 0.05$). Patients receiving HD at hospitals with an annual median number of ≥105 vascular access procedures also had a lower risk of 3-year infection than patients receiving HD at a hospital with an annual number of vascular access procedures less than median (HR 0.71; 95 % CI 0.54–0.93; $P < 0.05$) (Table 4).

After all the foregoing variables were included in a Cox regression analysis, the risks of 1- and 3-year infections were lower for patients in groups 2 and group 3 ($P < 0.05$) compared with group 1. Patients receiving HD at hospitals with an annual median number of ≥105 vascular access procedures still had a lower risk of 3-year infection (HR 0.70; 95 % CI 0.52–0.93; $P = 0.0153$). Male sex, age >64 years, and a CCI score of ≥3 remained as risk factors for 1- and 3-year infection in our patient cohort (Table 4). Early referral and the interaction between referral and group of vascular access conversion did not show significance in the 1- and 3-year infection rates (Table 4).

Table 4 Variables included in the Cox regression model to analyze the risk factors of infection

	Cox regression for 1-year infection-free days ($n = 644$)						Cox regression for 3-year infection-free days ($n = 644$)					
	Bivariate analysis			Multivariate analysis			Bivariate analysis			Multivariate analysis		
	HR	95 % CI	*P*	HR	95 % CI	*P*	HR	95 % CI	*P*	HR	95 % CI	*P*
Patient characteristics												
Vascular access conversion (base: group 1)												
Group 2	0.35	0.23–0.53	<0.0001	0.41	0.27–0.64	<0.0001	0.40	0.28–0.57	<0.0001	0.47	0.32–0.67	<0.0001
Group 3	0.47	0.23–0.97	0.0400	0.54	0.26–1.12	0.0968	0.46	0.25–0.88	0.0191	0.51	0.27–0.99	0.0452
Group 4	1.81	1.10–2.99	0.0195	1.50	0.90–2.51	0.1206	1.87	1.15–3.04	0.0112	1.58	0.97–2.60	0.0691
Sex (base: female)	1.12	0.83–1.52	0.4683	1.40	1.01–1.95	0.0432	1.12	0.86–1.47	0.4080	1.36	1.01–1.82	0.041
Age group (base: 18–64 years) (years)												
65–74	2.37	1.60–3.51	<0.0001	1.77	1.17–2.67	0.0069	2.42	1.71–3.43	<0.0001	1.88	1.30–2.71	0.0008
> 75	2.53	1.74–3.66	<0.0001	1.68	1.12–2.54	0.0131	2.65	1.91–3.69	<0.0001	1.79	1.24–2.57	0.0019
Education (base: ≤6 years) (years)												
≥7	0.63	0.44–0.90	0.0106	0.77	0.53–1.13	0.1855	0.66	0.49–0.90	0.0081	0.81	0.58–1.14	0.2293
Marital status (base: without spouse)	0.70	0.52–0.95	0.0238	0.80	0.57–1.11	0.1773	0.72	0.55–0.95	0.0189	0.80	0.59–1.07	0.1366
Urbanization (base: city)	0.95	0.70–1.30	0.7577	0.93	0.68–1.29	0.6803	0.99	0.75–1.30	0.9238	0.98	0.73–1.30	0.8609
Early referral to nephrologists (base: no)	0.87	0.62–1.21	0.3925	0.94	0.67–1.32	0.7339	0.83	0.62–1.13	0.2351	0.91	0.67–1.23	0.548
CCI (base ≤1)												
2	0.84	0.52–1.38	0.4968	0.76	0.44–1.32	0.3349	1.01	0.67–1.53	0.9519	1.00	0.62–1.59	0.9842
≥3	1.90	1.34–2.68	0.0003	1.46	0.87–2.44	0.1483	1.91	1.40–2.61	<0.0001	1.62	1.02–2.57	0.0414
Diabetes (base: 0)	1.41	1.03–1.92	0.0300	0.98	0.63–1.55	0.9417	1.34	1.02–1.75	0.04	0.90	0.60–1.35	0.6144
Hospital ownership (base: private)	1.56	1.14–2.13	0.0058	1.17	0.83–1.64	0.3663	1.57	1.18–2.09	0.0018	1.15	0.85–1.57	0.3651
Annual surgical number of vascular access at hospital (base: <median, 105 cases/year)	0.75	0.55–1.01	0.0603	0.73	0.53–1.00	0.0521	0.71	0.54–0.93	0.0124	0.70	0.52–0.93	0.0153

Group 1, incident patients with a permanent catheter for HD who did not have vascular access conversion during the first 120 days; group 2, patients with a permanent catheter who had the first vascular access conversion to AVF for HD during the first 120 days; group 3, patients with a permanent catheter who had the first vascular access conversion to AVG for HD during the first 120 days; group 4, patients with a permanent catheter who had the first vascular access conversion to a secondary permanent catheter (permanent catheter created following failure of initial permanent catheter was defined secondary permanent catheter) or to a temporary catheter for HD during the first 120 days

CCI Romano–Charlson comorbidity index

Discussion

The first year mortality rate in the study population (26.0 %, Table 2) is higher than in the total of incident HD patients (20.8 %, unpublished data of the Taiwan Society of Nephrology). The five common causes of death are cardiovascular disease (45.7 %), infection (24.2 %), malignancy (7.8 %), cerebrovascular disease (5.7 %) and gastrointestinal disease (5.1 %).

After controlling all other variables, patients in group 2 (HR 0.37, 95 % CI 0.24–0.58, $P < 0.0001$) or group 3 (HR 0.39, 95 % CI 0.17–0.88, $P < 0.05$) compared with group 1 had lower 1-year mortality. Our findings are consistent with those in previous reports of incident patients (HR 0.64–0.71) [13, 22, 23] and maintenance HD patients [14]. As well as the 1-year effect, this study found that lower mortality effect extended throughout the 3-year period in group 2 (HR 0.36, 95 % CI 0.24–0.52, $P < 0.0001$) and group 3 (HR 0.47, 95 % CI 0.25–0.87, $P < 0.05$). The 3-year mortality in group 2 patients was the lowest. These findings could be important to encourage and remind physicians and incident patients who start with a permanent catheter to receive vascular access conversion to AVF as soon as possible, and then AVG (Fig. 2). Patients with older age and CCI ≥2 may represent a subpopulation with a greater disease burden, and may be perceived by themselves, their care providers, or family as frail, with vein distensibility, greater risk of AVF failure, not in need of an invasive surgical procedure, and unable to withstand the procedure (Table 1) [24–28].

Our study also investigated the relationship between vascular access conversion and infection including sepsis, which has seldom been examined in previous reports on incident patients starting HD with a catheter [13, 22, 23, 29]. This study found that lower infection rates also extended throughout the 3-year period in group 2 (HR 0.47, 95 % CI 0.32–0.67, $P < 0.0001$) and group 3 (HR 0.51, 95 % CI 0.27–0.99, $P < 0.05$). In addition to the pattern of vascular access conversion in the present study, male sex, older age and CCI score of ≥3 were also found to be risk factors for infection and a lower number of infection-free days as in other reports [30, 31]. Patients who received AVF/AVG at hospitals with an annual median number of ≥105 vascular access procedures also had lower 3-year infection rates (Table 4). Although this negative association between hospitals with a higher annual number of vascular access procedures and infection has not been reported before, this finding could be supported by previous literature that higher hospital volume of specific procedures results in less infection [32, 33]. It might also imply that the performance of vascular access procedures in hospitals that perform a high annual number of procedures is better than in hospitals that perform a low annual number of procedures.

In this study, diabetes was associated with 1- and 3-year mortality and infection in bivariate Cox regression analysis ($P < 0.05$, Tables 3, 4), but not in multivariate Cox regression analysis ($P > 0.05$, Tables 3, 4). This data indicated that diabetes was a risk factor for mortality and infection, but competed with CCI in mortality and infection; CCI score played a more important role.

Although the pressure and motivation for nephrologists, surgeons, patients and family to create an AVF or AVG for incident patients to start HD with a permanent catheter may be reduced, the above finding of lower mortality and longer infection-free days in incident patients who start HD with a permanent catheter to receive vascular access conversion to AVF/AVG could encourage and remind physicians and incident patients to receive vascular access conversion to AVF/AVG.

Study limitations

Several limitations of our study deserve mention. First, we are unable in this historical cohort study to assess the contribution of clinical condition to our results, including patients with no access options or access maturation, severity of comorbidities, experience of the surgeon, patient compliance, efficacy of dialysis, reason for vascular access conversion, or laboratory data. We did, however, control for confounding factors such as age, CCI score, diabetes, hospital ownership, and annual number of vascular access procedures at a particular hospital, among others. As with all studies that use administrative datasets, the key comorbid conditions that contribute additional prognostic information over and above laboratory and clinical parameters were reported [34]. Second, previous reports did not define the time point at which incident patients underwent catheter insertion. Whether our definition of ‘within 3 days before start of HD’ as the cut-off point for selecting incident patients with a permanent catheter was the correct one may need further evaluation. Third, ‘vascular access conversion within the first 120 days’ was chosen as the cut-off point for evaluating mortality and infection in this study because of the fact that 80 % of incident patients receive vascular access conversion within this period. Whether this cut-off point for evaluating infection and mortality was the correct one may also need further investigation.

In conclusion, the effect of lower mortality and infection rate in incident patients who start HD with a permanent catheter and receive vascular access conversion to AVF/AVG can extend to 3 years. We should encourage and remind physicians and incident patients to receive vascular access conversion to AVF/AVG. The patients who received AVF/AVG at hospitals which perform a high annual number of vascular access procedures had lower 3-year infection rates.

Acknowledgments This study was supported by a grant (NSC 96-2314-B-075-020-MY3, NSC98-2314-B-010-007-MY2) from the National Science Council, and by the Szu-Yuan Research Foundation of Internal Medicine, Republic of China. We thank them for providing valuable suggestions.

Conflict of interest None.

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