INTRODUCTION

End-stage renal disease (ESRD) is a chronic disorder of kidney function, frequently associated with diabetes mellitus, that results in potentially fatal abnormalities of fluid and electrolyte function and accumulation of toxic metabolic waste products. When renal transplantation is not feasible, renal replacement therapy can be undertaken, using either haemodialysis or peritoneal dialysis. For haemodialysis treatments, vascular access is required and can consist of arteriovenous (AV) fistulae in the upper extremities or central vascular access catheters in the subclavian or jugular veins.

SUMMARY

Limited data are available about disability associated with upper extremity complications in patients who receive haemodialysis for end-stage renal disease. In this study of 123 patients receiving haemodialysis, the mean Disabilities of the Arm, Shoulder and Hand (DASH) score was 31 ± 22 points, indicating markedly greater disability than in a normal population. Dupuytren’s contracture was the most frequent deformity. Brachial, radial and ulnar pulses were present in most upper limbs, but 14 (14%) of 102 patients had poor arterial perfusion pressures. Diabetic patients had residual or complete loss of protective sensation more frequently than nondiabetic patients. Motor testing with the index finger abduction and fifth finger flexion tests showed a significantly greater frequency of weakness in diabetic than nondiabetic patients. In summary, upper extremity disability was noted in haemodialysis patients, including loss of protective sensation and motor strength, both in diabetic and nondiabetic subjects.

KEY WORDS Disability • Hand • Kidney • Neuropathy • Vascular • Weakness

BIONETWEIGHT

Scott Hurton is currently a first year resident in General Surgery, at Dalhousie University, Halifax, Nova Scotia, Canada. He graduated from the School of Medicine University of Manitoba, Winnipeg, Manitoba, Canada in 2010. His future areas of interest include surgical education and surgical oncology. While at the University of Manitoba, he also completed a Bachelor of Science in Medicine.

John Embil is a specialist in Internal Medicine and Infectious Diseases. He practices at the Health Sciences Centre, Winnipeg, Manitoba, Canada, an 800-bed tertiary care University-affiliated teaching hospital with a 300-patient haemodialysis patient population. His areas of active research include: infections in persons with diabetes; infections in persons receiving haemodialysis; peripheral neuropathy in persons with diabetes; wound healing; foot ulcerations in persons with diabetes; blastomycosis; hospital epidemiology and evaluation of new agents for wound healing and for the treatment of skin, soft tissue and bone infections. He has published nearly 200 articles in these areas.

CORRESPONDENCE

John M. Embil
Infection Prevention and Control Unit,
Health Sciences Centre,
MS673–820 Sherbrook Street,
Winnipeg, Manitoba, Canada R3A 1R9.
Tel.: (204) 787–4654
Fax: (204) 787–2989
jembil@hsc.mb.ca

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There are limited data about the upper extremity complications and disability associated with haemodialysis for ESRD (Calik et al. 2006). The abnormal electrolyte and metabolic status in haemodialysis patients may contribute to tissue damage resulting in musculoskeletal and neurological impairment of the upper extremities. These impairments may include muscle weakness and abnormal sensory function (Calik et al. 2006). Upper extremity complications also may be directly related to vascular access devices, such as central venous catheters or AV fistulae, and associated neurologic and ischaemic steal manifestations (Mattson 1987; Riggs et al. 1989; Hye & Wolf 1994; Redfern & Zimmerman 1995; Nicholas et al. 2000; Wixon et al. 2000; Knox et al. 2002; Diehl et al. 2003; Schanzer & Eisenberg 2004). A previous study of nerve conduction studies, noninvasive vascular studies and arteriography demonstrated that an AV fistula for haemodialysis may be complicated by ipsilateral ischaemia distal to the fistula, particularly in diabetic patients, and may result in amputation (Redfern & Zimmerman 1995). Furthermore, haemodialysis patients with diabetes mellitus also may have disturbed glycaemic control and diabetic neuropathy that may aggravate upper extremity impairment associated with ESRD.

Based on clinical observations, we hypothesised that patients with chronic renal failure receiving haemodialysis may develop complications in both upper extremities regardless of the type or location of vascular access device, and that these complications are more frequent in diabetic patients. The purpose of this study was to evaluate upper extremity complications ipsilateral and contralateral to vascular access devices, in nondiabetic and diabetic patients receiving haemodialysis for chronic renal failure.

**MATERIALS AND METHODS**

**SUBJECTS**

All 278 patients receiving haemodialysis for ESRD during a one-week period (4–9 June 2007) at a tertiary healthcare centre and affiliated regional centres were approached to participate in the study. Exclusion criteria were as follows:

- declined participation (80 patients);
- had a language or comprehension barrier or could not provide written informed consent (42 patients);
- were in isolation for infection control precautions (22 patients);
- were transferred to another facility (11 patients).

Two participating patients withdrew and one patient died, leaving 123 participants in the study. The study was approved by the University of Manitoba Human Research Ethics Committee.

**EVALUATION**

A standardised patient interview was performed and retrospective review of the medical records was undertaken to determine information about demographics, history and medical comorbidities. Aboriginal subjects were the indigenous inhabitants of Canada including the First Nations and Metis people without regard to their separate origins and political or cultural identities (Royal Commission on Aboriginal Peoples 1996); during the entire year 2007, there were 470 (34%) Aboriginal patients treated among the 1,382 patients treated in the provincial haemodialysis programme. The Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire was administered (Solway et al. 2002) to assess each individual patient’s assessment of his or her upper limb functionality. Body mass index (BMI) was determined as the ratio of weight (kg) divided by height (m) squared (Health Canada 2008).

A standardised examination of the hand and upper extremity was performed similar to that described for Hansen’s disease (Health Resources and Services Administration 2008) to evaluate motor and sensory function. Physical examination also included assessment for vascular complications, Dupuytren’s contractures and swan neck, boutonnière and mallet finger deformities.

The peripheral pulses were palpated in the radial, ulnar and brachial regions and graded as either present or absent. While receiving haemodialysis treatment, digital pressure studies were performed (Hadeco Smartdop® 45, Koven Technology Inc., St. Louis, MO, USA) on all 10 digits to objectively assess the level of perfusion in both upper extremities in 102 (83%) of the 123 patients; 21 (17%) patients were unavailable because of temporary or permanent movement to other dialysis centres. Cuffs were placed on the proximal phalanges, a probe was placed on the pad of the finger, a pulse was obtained on the monitor and the cuff was inflated until occlusion of the vessel occurred. Poor arterial perfusion pressure was defined as pressure less than 50 mm Hg. Transcutaneous oxygen studies were performed (TCM400, Radiometer America Inc., Westlake, OH, USA) on approximately 20 patients, but this portion of the study was abandoned because consistent results could not be obtained.
Muscle strength was assessed at the shoulder (abduction and adduction), elbow (flexion and extension), wrist (flexion and extension) and hand (fifth finger flexion, index abduction, thumb abduction, thumb and fifth finger opposition and flexor digitorum superficialis and profundus) (Hoppenfeld 1976).

Sensory assessment was performed using Semmes-Weinstein 0.05, 0.20, 2, 4, 10 and 300g monofilaments at seven sites on both hands: the palmar surface of the thumb distal phalanx, index proximal and distal phalanges, fifth finger proximal and distal phalanges, hypothenar eminence and the dorsal surface of the thumb metacarpal (Health Resources and Services Administration 2008). Since specific recommendations were not available for Semmes-Weinstein monofilament testing in the hands of diabetic patients, sensation was graded as abnormal if the patient did not appreciate the 2.00g monofilament, as defined in patients with leprosy (Health Resources and Services Administration 2008). The Upper Extremity Sensation Score was defined as zero points for normal sensation (monofilament with less than 2g of pressure) and one point for abnormal sensation (sensation to 2g, 4g, 10g or 300g monofilament) or no sensation. This score was calculated for each side (right or left) and combined as a total for both hands in each patient.

**DATA ANALYSIS**

Patient demographics and medical comorbidities were analysed for differences between nondiabetic and diabetic patients using Pearson and Spearman correlation tests, non-parametric Wilcoxon Scores (rank sums), standard chi-square, Mantel-Haenszel chi-square, t-tests and Fisher’s exact test. The DASH was analysed through chi-square tests and calculating Mantel-Haenszel chi-square, t-tests and Fisher’s exact test. The DASH Score (points) was compared for differences between nondiabetic and diabetic patients using Pearson and Spearman correlation tests, non-parametric Wilcoxon Scores (rank sums), standard chi-square, Mantel-Haenszel chi-square, t-tests and Fisher’s exact test. Differences were defined as significant if p < 0.05.

**RESULTS**

The majority of participants were diabetic, male and non-Aboriginal; nondiabetic patients were slightly older than diabetic patients (Table 1). Some patients were displaced from their home communities because they needed dialysis; more subjects lived in urban residences after than before beginning hemodialysis (Table 1). Mean duration of haemodialysis was similar for nondiabetic and diabetic patients (Table 1). Results of assessment of disability with the DASH questionnaire were similar for nondiabetic and diabetic patients (Table 1).

Diabetic patients had significantly greater mean body mass index and had greater frequency of obesity than nondiabetic patients (Table 2). DASH questionnaire responses were similar for all BMI categories. Diabetic patients more frequently had hypertension, myocardial infarction and congestive heart failure, but less frequently had undergone prior renal transplantation, than nondiabetic patients (Table 3). There were no significant differences between nondiabetic and diabetic patients in frequency of other comorbidities (Table 3).

Dupuytren’s contracture was the most frequent deformity identified on physical examination (Table 4). A significantly
greater proportion of temporary internal jugular catheters and radiocephalic AV fistulae that were present for more than one year were noted in nondiabetic than diabetic patients (Table 5), and there were no differences between nondiabetic and diabetic patients in frequency of all other fistulae, catheters and grafts considered separately. A significantly greater proportion of all access devices recorded (total and current) were present for more than one year in nondiabetic than diabetic patients (Table 5).

Brachial, radial and ulnar pulses were present in most upper limbs, and there was no difference in presence of pulses between nondiabetic and diabetic patients or between right and left upper limbs (Table 6). Fourteen (14%) of 102 patients had poor arterial perfusion pressures (data not available for 21 patients) (Norgren et al. 2007). However, there were no differences between the nondiabetic and diabetic patients in mean perfusion pressure or number of amputated fingers (data not shown). There was no significant difference in frequency of patients with poor arterial perfusion pressure between patients with fistulae compared with those with other types of vascular access, for both limbs ipsilateral (fistula, 9 (18%) of 51 patients;...
nonfistula, 3 (6%) of 47 patients; not significant) or contralateral [fistula, 3 (6%) of 51 patients; nonfistula, 2 (4%) of 47 patients; not significant] to the vascular access site. The frequency of patients (combined limbs ipsilateral and contralateral to the vascular access site) who had poor arterial perfusion pressure or at least one amputated finger was similar for patients with fistulae [12 (24%) of 51 patients] or without fistulae [6 (13%) of 47 patients; difference not significant].

Diabetic patients had residual or complete loss of protective sensation more frequently than nondiabetic patients, but sensory loss was not infrequent in nondiabetic patients (Table 7). The frequency of patients with abnormal sensory examination was greater for diabetic than nondiabetic patients for upper extremities both ipsilateral and contralateral to all vascular access devices (Table 8).

Motor testing with the index finger abduction and fifth finger flexion tests showed a significantly greater frequency of weakness in diabetic than nondiabetic patients (Table 7). There was no difference in strength between the nondiabetic and diabetic patients in thumb abduction, wrist extension, flexor digitorum superficialis and profundus, thumb abduction and adduction, elbow flexion and extension or shoulder adduction and abduction.

Right and left fifth finger flexion strength, and right (but not left) thumb abduction strength were more frequently abnormal in patients without a fistula than in patients with a fistula (Table 9). There was no difference in strength between the fistula and nonfistula patients in thumb abduction, wrist extension, flexor digitorum superficialis and profundus, thumb

<table>
<thead>
<tr>
<th>Site</th>
<th>Number (%) subjects with abnormal examination</th>
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<tbody>
<tr>
<td></td>
<td>Nondiabetic (N = 45)</td>
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<tr>
<td>Sensory testing⁵</td>
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<td>Palmar Thumb, distal phalanx</td>
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<td>Right</td>
<td>11 (24)</td>
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<td>Left</td>
<td>12 (27)</td>
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<td>Palmar Index, proximal phalanx</td>
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<td>Right</td>
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<td>Left</td>
<td>7 (16)</td>
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<td>Palmar Index, distal phalanx</td>
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<td>Right</td>
<td>8 (18)</td>
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<td>Left</td>
<td>6 (13)</td>
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<td>Palmar Fifth finger, distal phalanx</td>
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<td>Right</td>
<td>8 (18)</td>
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<td>8 (18)</td>
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<td>Palmar Fifth finger, proximal phalanx</td>
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<tr>
<td>Right</td>
<td>15 (33)</td>
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<td>Left</td>
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<td>Palmar Hypothenar eminence</td>
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<td>19 (42)</td>
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<tr>
<td>Dorsal Thumb metacarpal</td>
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<td>Right</td>
<td>10 (22)</td>
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<td>Left</td>
<td>11 (24)</td>
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<tr>
<td>Motor testing⁶</td>
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<td>Index Abduction test</td>
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<td>Right</td>
<td>15 (33)</td>
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<tr>
<td>Fifth finger Flexion test</td>
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<td>Right</td>
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<td>Left</td>
<td>5 (11)</td>
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Table 7: Sensory and motor abnormalities in nondiabetic and diabetic haemodialysis patients.
There were 11 patients for whom diabetes status was unknown. In addition, vascular evaluation was not available for one nondiabetic and four diabetic patients.

⁵Sensation was tested using 0.05, 0.20, 2.0, 4.0, 10.0 and 300.0 g Semmes-Weinstein monofilaments. Numbers reported are numbers of patients who had residual or no protective sensation, i.e. patients who did not sense the 2.0-g monofilament.

⁶Numbers reported are numbers of patients with abnormal index abduction and fifth finger flexion tests. There was no significant difference between the diabetic and non-diabetic groups with the thumb abduction from the palm, wrist extension, flexor digitorum superficialis and profundus, thumb abduction and adduction, elbow flexion and extension and shoulder adduction and abduction.

NS = Not significant (p > 0.05)
abduction and adduction, elbow flexion and extension and shoulder adduction and abduction.

**DISCUSSION**

The current data support the hypothesis that upper extremity complications develop in patients with chronic renal failure receiving haemodialysis regardless of type or location of vascular access, and that diabetes is a major risk factor for upper extremity neuropathy in haemodialysis patients. Diabetic patients showed more frequent sensory loss and motor weakness in the hand compared with non-diabetic patients. Clinical and non-invasive vascular evaluation did not reveal any significant differences in arterial perfusion between non-diabetic and diabetic patients. The current report extends previous work on upper extremity disability in haemodialysis patients (Calik et al. 2006) because the present study includes comparative data for diabetic and non-diabetic patients (Tables 1 to 8), data for patients with cardiovascular and neurological comorbidities (Table 3), and data for vascular access devices other than an AV fistula (Table 5) excluded from the previous report (Calik et al. 2006).

Haemodialysis is not available to some persons in their home communities, necessitating relocation or commuting to receive this life-saving treatment (Table 1). Relocation from remote communities precludes access to local support systems (Salvalaggio et al. 2003), and a drastic change in culture may be experienced, particularly for Aboriginal patients, some of who do not speak English (Health Canada 2000; Green 2003).

The DASH score was insensitive to differences between nondiabetic and diabetic patients (Table 1) despite the greater frequency of sensory and motor abnormalities in the diabetic than nondiabetic subjects observed in this study (Table 7) and reported previously (Borsey et al. 1983; Mota et al. 2000–2001; Smith et al. 2003). Higher DASH scores indicate greater disability, and the observed mean DASH scores were approximately three-fold greater than the mean DASH score of 10 ± 15 points noted in 1800 normal people in the United States (Hunsaker et al. 2002), consistent with a greater disability in the current study patients. This finding demonstrates marked physical disability in persons receiving haemodialysis regardless of the cause of end-stage renal failure. There was greater disability (higher DASH scores) in the present study than reported previously in haemodialysis patients (Calik et al. 2006), possibly because of the older average age of patients in the current study (Table 1) and inclusion of patients with cardiovascular and neurological comorbidities in the present study (Table 3) that were excluded from the previous report (Calik et al. 2006).

The greater mean BMI and frequency of patients with higher BMI in diabetic than nondiabetic patients (Table 2) are consistent with the known association between obesity and the risk of developing insulin resistance and type 2 diabetes (Haffner 2006; Dennett et al. 2008). The medical comorbidities observed more frequently in the diabetic patients (Table 3) were consistent with diabetic comorbidities observed in other studies (Beckman et al. 2002; Peter et al. 2008). Dupuytren’s contracture has been associated with diabetes (Mota et al.
patients; however, mortality was not a factor on survival of vascular access in the present study because only one patient died. It is unknown why hand weakness was observed more frequently in patients with no fistula compared with those having a fistula (Table 9); hand dominance may be a factor but was not evaluated in the present study.

Aboriginal people comprised a large proportion (41%) of the diabetic patients in this study, but few nondiabetic patients (4%) were Aboriginal (Table 1). In the province of Manitoba, Aboriginal people comprise 16.5% of the general population (Statistics Canada 2006); however, the age-adjusted prevalence of diagnosed diabetes is 2.86-fold greater in Aboriginal than non-Aboriginal men and 4.64-fold greater in Aboriginal than non-Aboriginal women (Green et al. 2003). Therefore, the over-representation of Aboriginal patients in the present study compared with the general population reflects the greater prevalence of diabetes and associated renal disease in this ethnic group, and reflects the higher representation of Aboriginal people in the haemodialysis patient population (34%) than in the general population.

LIMITATIONS WITH CONCLUSION

Limitations of study are similar to those inherent in a study with retrospective review of medical records, including missing or potentially unreliable data. Selection bias towards patients with less severe upper extremity complications may have resulted from exclusion of patients with a language or comprehension barrier or those in isolation for infection control. A greater variety of Semmes-Weinstein monofilaments could have been used in the 2.0–4.0 g range to further differentiate the loss of sensation in all haemodialysis patients. Documentation of previous vascular access was incomplete in many cases, limiting the analysis to current vascular access. Patients were examined and studied while they were undergoing haemodialysis treatment, and nonphysiologic flow conditions may have occurred when measuring digital pressure. In addition, patients having haemodialysis may be fatigued because of metabolic issues associated with uraemia, and this may have contributed to potential unreliability of muscle strength testing. Furthermore, the side of hand dominance was not documented, which limited the evaluation of the direct contribution of dominance to upper extremity morbidity. Longitudinal DASH scores were unavailable; DASH scores before and after fistula placement may be useful in future research to evaluate the effect of fistula placement on upper extremity complications.
extremity function. Nevertheless, the current study provides information that may contribute to the development of rehabilitation programmes to maintain and optimise upper extremity function in haemodialysis patients.

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UPPER EXTREMITY COMPLICATIONS IN PATIENTS WITH CHRONIC RENAL FAILURE RECEIVING HAEMODIALYSIS


