Steal syndrome complicating upper extremity hemoaccess procedures: incidence and risk factors

Dion Davidson, MD;[*] George Louridas, MD;[*] Randolph Guzman, MD;[*] John Tanner, MD;[*] Wendy Weighell, RN;[*] Jodi Spelay, MD;[†] Dan Chateau, PhD[‡]

Introduction: Steal syndrome is a potentially grave complication of upper extremity hemoaccess (HA) in patients with renal failure. To determine the incidence and risk factors for steal in these patients at the St. Boniface Hospital, Winnipeg, a tertiary care centre for vascular surgery and dialysis, we reviewed data from patients requiring hemodialysis between September 1986 and July 2000. **Patients and methods:** We excluded all venous catheter and lower extremity procedures. There remained 325 upper extremity procedures in 217 patients. Data were collected from the patients' charts or by interview. First by univariate analysis and then by multivariate analysis for independent risk factors, we studied the effect on the development of steal of age, sex, race diabetes mellitus, hypertension, coronary artery disease or cerebrovascular disease, smoking, proximal procedures based on the brachial artery, distal procedures based on the radial artery, the use of prosthetic graft material and the creation of autologous fistulas. **Results:** The incidence of steal was 6.2%. The significant independent risk factors were diabetes mellitus (odds ratio [OR] 5.00, 95% confidence interval [CI] 1.39–18.08, $p = 0.01$) and Aboriginal race (OR 3.59, 95% CI 1.07–12.04, $p = 0.04$). An increasing risk for each year of advancing age at the time of procedure was suggested but was not significant (OR 1.04, 95% CI 1.00–1.09 $p = 0.07$). **Conclusions:** Patients who are diabetic or Aboriginal are at increased risk for steal with upper extremity HA procedures. This knowledge can guide discussion of dialysis options and informed consent. If upper extremity HA procedures are undertaken in patients at risk, they should be closely monitored and early intervention applied if necessary.

Introduction : Le syndrome d'hémodétournement est une complication de l'hémoaccès (HA) dans les membres supérieurs qui peut être grave chez les patients atteints d'insuffisance rénale. Afin de déterminer l'incidence et les facteurs de risque d'hémodétournement chez ces patients traités à l'Hôpital de Saint-Boniface (Winnipeg), centre de soins tertiaires en chirurgie vasculaire et dialyse, nous avons analysé des données sur des patients qui ont eu besoin d'hémodialyse entre septembre 1986 et juillet 2000. **Patients et méthodes :** Nous avons exclu toutes les interventions comportant la mise en place d'un cathéter veineux et les interventions pratiquées aux membres inférieurs. Il est resté 325 interventions pratiquées aux membres supérieurs chez 217 patients. On a recueilli des données dans les dossiers des patients ou en procédant à des entrevues. Nous avons étudié, d'abord par analyse unidimensionnelle et ensuite par analyse multidimensionnelle, des facteurs de risque indépendants, l'effet qu'ont sur l'apparition de l'hémodétournement l'âge, le sexe, la race, le diabète sucré, l'hypertension, la coronaropathie ou la maladie cérébrale vasculaire, le tabagisme, les interventions proximales basées sur l'artère brachiale, les interventions distales basées sur l'artère radiale, l'utilisation de matériel de greffe et la création de fistules autologues. **Résultats :** L'incidence de l'hémodétournement s'est établie à 6,2 %. Les facteurs de risque indépendants significatifs étaient le diabète sucré (coefficient de probabilité [CP] 5,00, intervalle de confiance [IC] à 95 %, 1,39–18,08, $p = 0,01$) et la race autochtone (CP 3,59, IC à

*From the *Division of Vascular Surgery, Department of Surgery, St. Boniface Hospital and University of Manitoba, Winnipeg, Man., the †Division of Vascular Surgery, Department of Surgery, University of Saskatchewan, Saskatoon, Sask. and the ‡Biostatistical Consulting Unit, Department of Community Health Sciences, Faculty of Medicine, University of Manitoba, Winnipeg, Man.*

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Correspondence to: *Dr. Dion Davidson, 845 Westminster Ave., Winnipeg MB R3G 1A7; fax 204 237-3429; diondavidson@hotmail.com*

95 %, 1,07–12,04, p = 0,04). On a laissé entendre que le risque pouvait augmenter en fonction de l'âge au moment de l'intervention, mais l'augmentation n'était pas significative (CP 1,04, IC à 95 %, 1,00–1,09, p = 0,07). **Conclusions :** Les patients diabétiques autochtones présentent un risque accru d'hémodétournement en cas d'intervention HA pratiquée aux membres supérieurs. Ces connaissances peuvent guider la discussion sur des méthodes possibles de dialyse et le consentement éclairé. Si l'on entreprend des interventions HA aux membres supérieurs chez des patients à risque, il faut les suivre de près et intervenir rapidement au besoin.

There are an estimated 10 000 patients receiving hemodialysis in Canada, and this number is expected to increase to 14 000 by 2005.[1] The creation and maintenance of hemoaccess (HA) sites for this expanding patient population are major concerns and represent a significant proportion of vascular surgical practice. The maintenance of HA sites is estimated to account for 25% of the total health care cost for patients with end-stage renal disease in the United States.[2]

The most common HA complication is thrombosis. Most often this can be treated successfully and with reasonably low morbidity while maintaining the access site. Another complication encountered in patients with upper extremity HA is distal ischemia, often referred to as steal syndrome. The phenomenon of steal represents a spectrum of disease. It is variably discussed in the literature as hand numbness or tingling, pain or loss of function or even tissue loss. Steal is not as common as thrombosis but can be much more difficult to treat and will often result in loss of the HA site and, rarely, amputation.[3]

Although numerous reports detail the phenomenon of steal syndrome in HA procedures, basic questions concerning its incidence and risk factors have not been adequately explored. The definition of the complication is not always clear and the reported rates are variable. Authors relying on a clearly stated clinical definition (persistent and severe symptoms) have cited rates between 1.6% and 6.3%.[4–8]

Reports on the risk factors for steal are sometimes conflicting; opinions include advancing age, female sex, diabetes mellitus, hypertension, atherosclerosis (coronary artery disease [CAD], cerebrovascular disease [CVD] or peripheral vascular disease [PVD]), proximal procedures based on the brachial artery and the use of polytetrafluoroethylene (PTFE) prostheses.[8–15] Before we carried out this review, there was the clinical impression at our institution that Aboriginal people were overrepresented among patients with steal syndrome.

There is considerable overlap among these clinical and surgical factors, and reviews involving large numbers of procedures and adequate statistical analysis of predictors are lacking. This has left fundamental questions unanswered concerning which patients are at risk.[16] A clear analysis to determine the risks for this serious complication is needed.

Patients and methods

Starting in September 1998 the charts of all patients at St. Boniface Hospital, Winnipeg, who required HA were reviewed and the information was entered into a database in an effort to assess overall outcomes for HA procedures. Since then, data on consecutive patients have been entered prospectively. After excluding venous catheter and lower extremity HA procedures, there remained 325 upper extremity HA procedures on 217 patients. The earliest procedure considered was performed in September 1986 and the last in July 2000. The clinical and surgical features related to these procedures are outlined in Table 1.

Data were collected by chart review and patient interview. Racial status and the presence or absence of clinical features such as diabetes mellitus, were therefore ascertained, according to reporting by the patient or clinicians involved in the patient's care. A history of either CAD or CVD was used as a marker for atherosclerosis in general. PVD was not specifically assessed.

The definition of steal used was the development of severe and persistent symptoms consisting of pain or weakness distal to the HA site. The symptoms were temporally related to the HA surgery. Some, but not all, of these patients experienced some degree of necrosis and tissue loss.

Statistical analysis of the possible risk factors for steal was performed by logistic regression. Multivariate analysis was performed using stepwise lo-

Table 1

Characteristics of 325 Upper Extremity Hemoaccess Procedures

Characteristics	No. (and %) of procedures*
Mean (and range) age at procedure, yr	66.0 (18–86)
Men	171 (52.6)
Women	154 (47.4)
Race	
Caucasian	234 (72.0)
Aboriginal	40 (12.3)
Other	51 (15.7)
Diabetes mellitus	164 (50.5)
Hypertension	271 (83.4)
CAD or CVD	187 (57.5)
Smoking	
Yes	52 (16.0)
No or quit	219 (67.4)
Unknown	54 (16.6)
Proximal procedures (brachial artery)	230 (70.8)
Distal procedures (radial artery)	95 (29.2)
Polytetrafluoroethylene grafts	163 (50.2)
Autologous fistulas	162 (49.8)

*Unless otherwise indicated.
CAD = coronary artery disease, CVD = cerebrovascular disease,

gistic regression with factors retained if the p value was less than 0.1.

Results

Of the 325 procedures, 20 (6.2%) resulted in steal syndrome in 20 patients. The characteristics of these patients are given in Table 2. No patient suffered more than 1 episode of steal. More recently, we have used the distal revascularization and interval ligation (DRIL) procedure, but of the 20 earlier cases represented in the present study, the access site was sacrificed in 14. Four patients were treated nonoperatively. Although these patients had severe symptoms, it was felt that because other access options were limited and because tissue loss was not significant, conservative management with close observation was the best approach. Three of these patients continued to tolerate their symptoms and remained on dialysis; the fourth died.

On simple observation of patient characteristics and details of surgery (Table 2), the patients with steal syndrome display many of the previously suggested risk factors. When compared with the overall population, they are older, with a higher proportion of women and Aboriginal people, diabetic and hypertensive patients and patients with either CAD or CVD. Proximal procedures based on the brachial artery and those procedures that utilize PTFE graft material are also overrepresented.

A univariate analysis was first performed to examine associations between potential risk factors and steal (Table 3). Many of the initial observations appear to persist. While smoking and hypertension are clearly not significant, advancing age and Aboriginal race display trends. CAD or CVD, proximal procedures involving the brachial artery, female sex, PTFE graft material and diabetes mellitus are all statistically significant.

Multivariate analysis was performed to assess which of the risk factors suggested by the univariate analysis were truly independent. Diabetes mellitus was found to be the single best independent predictor for the development of steal (odds ratio [OR] 5.00, 95% confidence interval [CI] 1.39–18.08, $p = 0.01$) (Table 4). Aboriginal race was also found to be a strong and independent risk factor (OR 3.59, 95% CI 1.07–12.04, $p = 0.04$). Although age did not reach strict statistical significance, the narrow CI for the small OR of 1.04 may represent a small but real increase in risk for each year of advancing age. After controlling for these 3 risk factors, the question of the risk of proximal procedures based on the brachial artery is still open. Although the OR is high (6.28), such large proportions of patients in both the overall and steal populations had proximal procedures that comparisons are difficult and cannot be made with confidence. Because the

Table 2

Characteristics of 20 Cases of Steal Syndrome

Characteristics	No. (and %) of cases*
Median (and range) age at procedure, yr	67.5 (55–82)
Men	7 (35)
Women	13 (65)
Race	
Caucasian	12 (60)
Aboriginal	5 (25)
Other	3 (15)
Diabetes	18 (90)
Hypertension	18 (90)
CAD or CVD	14 (70)
Smoking	
Yes	2 (10)
No or quit	13 (65)
Unknown	5 (25)
Proximal procedures (brachial artery)	19 (95)
Distal procedures (radial artery)	1 (5)
Polytetrafluoroethylene grafts	15 (75)
Autologous fistulas	5 (25)
Treatment	
Ligation	10 (50)
Removal	4 (20)
Banding	2 (10)
Conservative	4 (20)

*Unless otherwise indicated.
CAD = coronary artery disease, CVD = cerebrovascular disease.

Table 3

Univariate Analysis of Suggested Risk Factors for Steal

Risk factor	Odds ratio	95% confidence interval	p value
Diabetes mellitus	6.04	1.74–21.01	0.005
Polytetrafluoroethylene graft	3.16	1.12–8.91	0.03
Female sex	2.77	1.04–7.39	0.04
Proximal procedure	8.42	1.11–63.84	0.04
CAD or CVD	2.70	1.02–7.08	0.05
Aboriginal race	2.58	0.88–7.54	0.08
Age	1.03	0.99–1.06	0.10
Smoking	0.57	0.13–2.53	0.46
Hypertension	1.16	0.33–4.10	0.82

CAD = coronary artery disease, CVD = cerebrovascular disease.

Table 4

Multivariate Stepwise Logistic Regression Analysis of Suggested Risk Factors for Steal

Risk factor	Odds ratio	95% confidence interval	p value
Diabetes mellitus	5.00	1.39–18.08	0.01
Aboriginal race	3.59	1.07–12.04	0.04
Age	1.04	1.00–1.09	0.07
Proximal procedure	6.28	0.79–49.90	0.08
Female sex	2.21	0.79–6.18	0.13

numbers of patients with distal procedures in both groups are small, the CI for the OR (0.79–49.90) is quite wide, with the lower value less than 1, and statistical significance is not reached. Whether a proximal procedure is an independent risk factor for the development of steal cannot be established based on the present data.

Finally, after controlling for the above factors, female sex, although statistically significant on univariate testing, is unimportant as an independent risk factor. It was not retained by formal stepwise analysis. Regression analysis after the formal stepwise process confirmed that female sex is not significant in predicting steal. Similarly, analyzing the other factors suggested by univariate analysis, PTFE grafts and the presence of either CAD or CVD, revealed that these factors were also not related to steal once the other factors were accounted for (results not shown, $p > 0.25$).

Analysis of the possibilities of first-order interactions between diabetes mellitus and Aboriginal race revealed no significant interactions. In other words, the significant ORs in the multivariate analysis can be thought of as roughly additive rather than multiplicative.

Discussion

Ischemia distal to upper extremity HA procedures was first described in 1969[17] and was later termed "steal syndrome."[18] Knowledge of the independent risk factors for steal could lead to better dialysis planning and clarify which patients need to be monitored more intensely if upper extremity HA surgery is performed.

The diagnosis of steal for this review was a clinical one, and laboratory testing was not routinely performed. There are other conditions such as carpal tunnel syndrome that can mimic some of the symptoms of steal. Other authors report confirmation of steal with tests such as photoplethysmography; however, there is some controversy regarding what constitutes the diagnosis and the relative importance of clinical versus laboratory information. It is possible that some of the cases of steal in our study were misdiagnosed, and this misclassification could have led to a falsely elevated rate of steal and unknown effects on the determination of risk factors. However, the diagnosis in our patients was supported by the temporal relation of symptoms to the construction of the grafts and fistulas. Also, of the 14 patients whose fistula or graft was ligated or removed, all had prompt relief of symptoms.

Our results show an overall rate of steal of 6.2%. This is among the higher rates reported in the literature and can be explained to a large degree by the importance of diabetes mellitus. There are few publications that clearly report both the rate of clinical steal and the rate of diabetes mellitus in their overall upper extremity HA populations. However, the relationship between diabetes mellitus and steal, when reported, is consistent: Zerbino and colleagues[5] reported rates of 12.9% and 1.9%, respectively, and Goff and associates[15] reported rates of 48.0% and 5.5%. The rate of diabetes mellitus in our population was 50.5%. In terms of the other definite independent risk factor, there have been no previous reports discussing both steal syndrome and Aboriginal race. Presumably the proportion of Aboriginals (or those of Native American descent) in our upper extremity HA population is substantial compared with others in the literature.

The pathophysiology relating diabetes mellitus to steal syndrome has been studied and reported. Eliades and Eliades[13] theorized that medial calcinosis can limit the size to which collateral arteries can expand to compensate for decreased flow distal to an HA site. Neuropathy may also blunt the autonomic response of vessels, further rendering them unable to adapt to the changes brought on by HA procedures. The reason for the increased risk among Aboriginal people is not clear. It may be related to a clinical factor not specifically analyzed by our study, such as PVD of the upper extremity.

It is possible that PVD may correlate more closely with steal than do CAD and CVD, markers of central atherosclerosis. Due to the retrospective nature of much of our data collection, it was impossible to evaluate the role of PVD. We were forced to use the more central markers of atherosclerosis because information regarding PVD (such as a history of claudication) was lacking in the charts. Similarly, information regarding the status of the upper extremity pulses was not consistently available in the charts and therefore could not be entered into the analysis. It is possible that a number of the diabetic patients in this study had diminished distal arm pulses, indicating occlusive disease and therefore compromised inflow at the wrist. Compromised inflow could account for some proportion of the effect of diabetes mellitus on the development of steal. Also, clinicians may have been more likely to pursue proximal HA if they thought the patient had distal occlusive disease. This could have confounded the trend seen associating steal to proximal procedures. The recording of simple clinical markers such as distal radial or ulnar pulses could, in the future, be analyzed for their specific and independent effect on the development of steal.

More comprehensive, prospective data collection would improve on the limitations of our study with regard to PVD and specifically distal occlusive disease in the upper extremity. Also, it would provide more information regarding smoking, although the missing data points are unlikely to have introduced any bias. The other shortcoming of the present study, the inability to evaluate the role of proximal procedures due to small numbers, can also be im-

proved by ongoing data collection.

Some have suggested that proximal procedures may actually serve diabetic patients better than distal procedures because maturation of the distal vessels can be impeded in the presence of diabetes mellitus. This makes the risk of proximal procedures for steal more important. Further study involving larger numbers of patients would clarify whether procedures based on the brachial artery truly represent an independent risk for the development of steal syndrome. Meanwhile, choosing the best HA strategy in diabetic patients remains challenging. Generally, at our centre, a distal procedure is preferred in all patients, including diabetics. Poor distal pulses may lead to the patient being offered a procedure based on the brachial artery, with the understanding that the risk of steal syndrome is probably substantial. A proximal upper extremity HA procedure, accepting the risk of steal, is usually preferable to a central venous catheter or an HA site located in the thigh. All diabetic patients with upper extremity HA sites are monitored closely for symptoms and signs of steal, and if the complication occurs, then ligation or the DRIL procedure are pursued.

The present review is among the largest in the literature and, to our knowledge after careful review, the only study to evaluate independent risk factors for steal syndrome by using multivariate analysis. The only proven independent risk factors for the development of steal are diabetes mellitus and Aboriginal race. A role for advancing age is also suggested, but did not reach statistical significance. Our raw data reveal that a diabetic Aboriginal person is approximately 10 times more likely to develop steal as a non-diabetic non-Aboriginal person (12.9% v. 1.3%).

Conclusions

Patients requiring HA procedures who are diabetic, Aboriginal, or both, need to be informed that they are at greater risk for the development of the steal syndrome. Knowledge of this risk may contribute to a decision of peritoneal dialysis rather than hemodialysis if this is feasible. Also, especially in an elderly patient with a limited life expectancy, a venous catheter may be a reasonable alternative. If an upper extremity HA procedure becomes necessary, these patients need to be monitored particularly closely for the signs and symptoms of steal. Surgical intervention, either by sacrifice of the access site or by the more recently established DRIL procedure, should be considered early to prevent the possible destructive consequences. The role of age as an independent risk factor should be analysed in prospective, large series.

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