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# Steal in Hemodialysis Patients Depends on Type of Vascular Access

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***Objectives***. *To study incidence and severity of steal phenomena in hemodialysis patients and to investigate possible methods for its detection.*
***Methods***. *A questionnaire was composed based on a literature search. A subgroup of patients having steal as identified by the questionnaire was studied using physical examination, arterial blood pressure, skin temperature, digital oxygenation, grip strength and plethysmography. Contralateral arms served as controls.*
***Results***. *A cold hand was present in 50% of the patients with a brachiocephalic (BC) arteriovenous fistula (AVF,* $n = 28$*) compared to 25% of prosthetic forearm loops (loop,* $n = 27$*) and 12% of the radiocephalic (RC,* $n = 65$, $p < 0.05$*) fistulas. Diabetics were at risk for steal (*$p < 0.001$*). Intensity of steal was not related to magnitude of access flow. Digital skin temperatures and grip strength were lower in steal hands (*$p < 0.02$*). Manual compression of the AVF normalised low digital pressures in steal hands (*$106 \pm 33$ *vs* $154 \pm 25$ *mm Hg,* $p < 0.001$*, contralateral side* $155 \pm 21$ *mm Hg).*
***Conclusions***. *Mild to moderate steal symptoms are common in a hemodialysis patient. Individuals with a BC are at a higher risk for developing complaints associated with reduced hand circulation compared to patients with a RC or loop. Low finger pressures in the presence of steal symptoms are usually reversible.*

*Keywords: Hemodialysis; Steal; Vascular access; Arteriovenous fistula.*

## Introduction

For haemodialysis an arteriovenous fistula (AVF) placed at the wrist (radiocephalic fistula, 'RC') is thought superior by most surgeons. Although some prefer an autogenous brachiocubital fistula (elbow, 'BC') as a second choice, others prefer an access positioned at the forearm using a prosthetic graft loop fistula ('loop').[1]

Functioning of any type of AVF is largely dependent on blood flow. Thrombosis and occlusion may occur if fistula flow drops below a minimal threshold value. In contrast, greatly augmented flows may lead to ischemia of the forearm and hand.[2] In the latter situation, blood flow is directed towards the AVF leading to peripheral 'steal' phenomena.[3] Steal is thought to occur more easily if a fistula is located in a proximal portions of the upper extremity and its intensity may be related to blood flow velocity through the arteriovenous anastomosis.

Subjective symptoms of steal are characterized by coldness, pain, cramps and altered sensibility. Frequency and intensity of mild and moderate steal are unknown. Incidence of severe steal is 0.5 to 5%.[4] In addition, an objective 'gold standard' method that clearly discriminates between presence or absence of ischemia in a hemodialysis arm has not been identified although low finger pressures may be associated with steal.[5,6]

The present study has two aims. Firstly, to study incidence of steal phenomena in patient populations with three different dialysis accesses. Secondly, to investigate whether diagnostic tools are capable of detecting steal in hemodialysis patients reporting ischemic symptoms.

## Patients and Methods

### *A. Study population and questionnaire*

The study was conducted between January 2003 and January 2004. Patients were recruited from two

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dialysis facilities (Veldhoven, $n = 90$, and Maastricht $n = 67$). Only patients receiving chronic hemodialysis (>6 months) and having well-functioning dialysis accesses were eligible for the study ($n = 157$). Patients were not studied if they refused ($n = 14$), or displayed a cognitive ($n = 15$) or language ($n = 8$) handicap. The remainder of the patients ($n = 120$) were informed on the nature of the study and consented to its specifics.

A search was conducted on literature related to steal in the presence of a dialysis fistula using standard computer searching strategies. These data were used to compose a questionnaire aimed at studying incidence and severity of steal symptomatology. Questionnaires were completed by patients themselves under close supervision of one of two dedicated nurses belonging to the access surveillance team.

Severity of steal was evaluated using a Visual Analog Scale (VAS, 0 = no complaints, 10 = maximum of complaints). Frequency of symptoms was measured with similar VAS-techniques (0 = never, 10 = always). The 'steal score' of each individual was calculated as the sum of coldness (severity (s) × frequency (f), pain (s × f), loss of sensibility (s × f), loss of strength (s × f) and cramps (s × f, see 'appendix' for details).

This steal questionnaire was initially tested in a group of 25 patients. Their steal scores indicated that 14 individuals experienced symptoms of steal to a certain extent (mean steal score: $60 \pm 10$, range: 1−189) whereas 11 did not (steal score = 0). The questionnaire was completed by the entire study population ($n = 120$) at a later stage of the study.

All arteriovenous fistulas were created using standard techniques. The RC fistula were all end-(cephalic vein) to-side (radial artery) constructions. The BC group harboured 79% end-(Gracz vein) to-side (brachial artery), and 21% side-(Gracz vein) to-side (brachial artery). All prosthetic loops were connected between the brachial artery and a neighbouring vein; none had tapered or expanded ends (6 mm, PTFE, Gore and Assoc., Flagstaff, USA).

### *B. Steal detection techniques*

Results of the steal questionnaire obtained from the 25 patient pilot study indicated that 14 individuals subjectively experienced symptomatology possibly associated with the presence of steal. It was assumed that selected tools were capable of detecting steal in dialysis access arms in this subgroup. Measurements of the contralateral arm provided control values. All studies were performed just before the start of a dialysis session.

Physical examination of both arms and hands including inspection revealed if skin color was normal, or whether pallor or cyanosis were visible. Also the presence of trophic lesions (nails, loss of hair, muscle atrophy), ulcers or diminished capillary refill (>3 sec) was tabulated. Pulsations of both radial and ulnar arteries were scored (absent (0), weak (1), diminished (2) or normal (3)). Sensibility of the skin of the hand was tested using two point discrimination (sharp/soft) and was scored as normal (score = 2, all three tests were felt similar to the contralateral arm), diminished (1, at least one out of three tests was correctly sensed by the patient) or absent (0, no test was correctly counted by the patient). Skin temperatures of both dorsum and palm of the dialysis hand were compared with the contralateral side by the principal investigator (FvH) and subjectively scored as similar or colder.

Blood pressure of the contralateral brachial artery was determined with the patient in a sitting position. Bilateral measurements of systolic blood pressure in the radial and ulnar artery were performed using standard Doppler equipment (Dopplex, Huntleigh Diagnostics, Cardiff, UK). Skin temperature of various portions of the hand was measured using a digital thermometer (Genius First Temp, M 3000A, Sherwood Medical, Sussex, UK). The sensor was held at a 45 degree angle 1 cm above the skin, and measurements were done of dorsal and palmar portions of the hand as well as the distal phalanx of the index finger. Also oxygen saturation of the index finger was measured using a standard saturation meter (Ohmeda Biox, 3700e, Pulse oximeter, Louisville, USA). Capillary blood gas specimens were obtained from palmar portions of the index finger and analyzed using standard laboratory techniques (ABL700 FLEX, Radiometer, Copenhagen, Denmark). Grip strength of both hands was measured using hydraulic hand grip dynamometry (SH 5001, SAEHAN Corp, Korea). The patient was standing with the dynamometer in an extended arm. Subsequently, the arm was flexed 90 degrees while maximally squeezing the calipers. This exercise was repeated twice, and the best result was noted. Plethysmography was used to determine pressures of the index finger of both hands (VasoGuard Nicolet, 8 Mhz, Scimed Ltd, Bristol, UK), during manual compression of the venous portion of the AVF as well as during the open/normal situation. An inflatable cuff was wrapped around the proximal phalanx of the index finger and the sensor was positioned on the palmar side of the distal phalanx. The digital brachial index (DBI) was calculated as the ratio of finger pressure to systolic blood pressure.

Access flow was measured in duplicate using the transonic flowmeter and expressed in ml/min (HD01, Transonic Systems Inc, New York, USA).[7]

### *Statistical analysis*

Data were expressed as mean ± sd (or sem). Differences between groups with respect to the steal questionnaire were determined using Chi-square tests. Access flows were compared using an univariate analysis of variance. Non-parametric tests (Kruskal-Wallis) were used to determine group differences in severity and frequency of steal. Paired T-tests or Wilcoxon signed rank tests were performed when appropriate. A $p < 0.05$ was considered significant.

## Results

### *A. Steal questionnaire*

The questionnaire was completed by 120 patients. More than half of this population had a RC ($n = 65$), whereas approximately one quarter had a BC ($n = 28$) or a prosthetic forearm loop ($n = 27$) for hemodialysis. These three groups of patients were similar with respect to age, sex distribution, percentage of diabetes mellitus and access flow (Table 1). Cold sensation was reported more frequently in the BC-group when compared to the RC-group. Also a trend was present for cramps to occur more frequently in the BC-group. The majority of BC-patients (79%) complained of at least one symptom of steal compared to the RC-group (38%) ($p < 0.05$) or the loop-group (52%, Fig. 1). Severity and frequency of steal symptomatology as measured by a VAS score are depicted in Table 2.

Type of access did not influence frequency and severity of reported steal. In other words, if steal was present, its symptomatology was not more pronounced in one type of access compared to another. These VAS scores also indicate that symptomatic patients in the three different populations very frequently experience cold sensation (range 6.4–7.7) of moderate severity (4.6–6.4). Symptomatic patients also frequently (5.1–6.6) suffered from pain of mild (3.7–3.8) intensity. Most patients experience cramps only now and then. In contrast, diminished strength was almost always present (6.8–7.8) in symptomatic patients. The steal score ranged from 0 ($n = 31$ patients, total absence of any symptom traditionally associated with steal) to 1–276 ($n = 89$ patients, had

**Table 1. Characteristics of dialysis study population ($n = 120$) that completed a steal questionnaire**

| | RC | BC | Loop | *p* |
|---|---|---|---|---|
| N | 65 | 28 | 27 | |
| Age (y) | 66 ± 13 | 65 ± 14 | 69 ± 10 | 0.73[a] |
| Male N (%) | 42 (65) | 15 (54) | 11 (41) | 0.10[a] |
| Diabetes mellitus N (%) | 11 (17) | 6 (21) | 1 (4) | 0.15[a] |
| AVF flow (ml/min) | 855 ± 466 | 1147 ± 724 | 1040 ± 409 | 0.86[b] |

[a] Chi-square.
[b] Univariate Analysis of Variance.

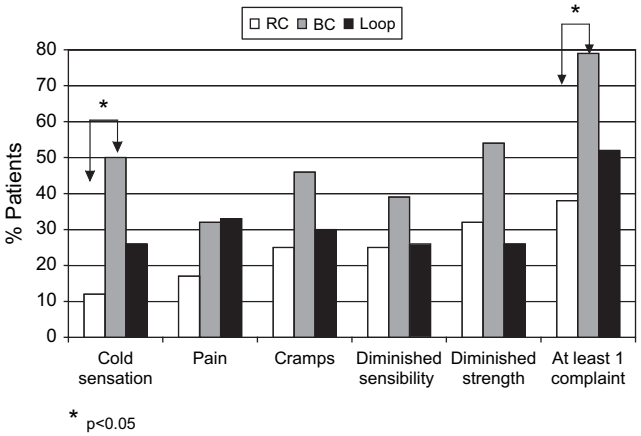


**Fig. 1.** Incidence of steal symptoms as identified by a steal questionnaire in 3 different groups of dialysis accesses (RC = 65, BC = 28, loop = 27).

**Table 2. Severity and frequency of symptoms of steal that was reported by patients (N) with three different dialysis accesses (VAS, 0 (min)–10 (max)**

| | | RC (65) | BC (28) | Loop (27) | *p* |
|---|---|---|---|---|---|
| Cold sensation | N (%) | 8 (12) | 14[a] (50) | 7 (26) | <0.001[d] |
| | Severity | 5.1 ± 3.1 | 6.4 ± 3.0 | 4.6 ± 3.5 | 0.36[e] |
| | Frequency | 6.4 ± 3.3 | 7.7 ± 2.7 | 7.6 ± 2.8 | 0.65[e] |
| Pain | N (%) | 11 (17) | 9 (32) | 9 (33) | 0.13[d] |
| | Severity | 3.7 ± 2.0 | 3.8 ± 2.1 | 3.7 ± 2.1 | 0.96[e] |
| | Frequency | 5.6 ± 3.3 | 5.1 ± 1.9 | 6.6 ± 3.2 | 0.64[e] |
| Cramps | N (%) | 16 (25) | 13 (46) | 8 (30) | 0.08[d] |
| | Severity | 3.2 ± 1.1 | 3.3 ± 0.9 | 3.4 ± 1.2 | 1.0[e] |
| | Frequency | 3.9 ± 1.3 | 4.1 ± 1.4 | 4.5 ± 1.7 | 0.8[e] |
| Diminished sensibility | N (%) | 16 (25) | 11 (39) | 7 (26) | 0.34[d] |
| | Severity | 4.8 ± 2.6 | 5.3 ± 2.8 | 5.3 ± 3.4 | 0.92[e] |
| | Frequency | 7.0 ± 3.5 | 6.2 ± 3.4 | 5.1 ± 2.6 | 0.46[e] |
| Diminished strength | N (%) | 21 (32) | 15 (54) | 7 (26) | 0.12[d] |
| | Severity | 5.0 ± 1.8 | 5.4 ± 1.9 | 5.6 ± 3.0 | 0.85[e] |
| | Frequency | 7.8 ± 2.6 | 6.8 ± 3.7[b] | 7.4 ± 4.1 | 0.03[e] |
| Minimal 1 complaint | N (%) | 25 (38) | 22[c] (79) | 14 (52) | 0.01[d] |

[a] $p < 0.001$ versus RC.
[b] $p < 0.01$ versus RC.
[c] $p < 0.05$ versus RC.
[d] Chi-square.
[e] Kruskal Wallis.

minor to extremely severe symptomatology of steal). The relationship between steal scores and access flow for all 120 patients is depicted in Fig. 2. Contrary to what one would expect, patients with high flows did not report more symptomatology associated with steal compared to patients with low flow accesses ($p = 0.30$). However, diabetics ($n = 18$) displayed higher steal scores compared to non-diabetics ($85 \pm 20$ vs $36 \pm 5$, $p < 0.001$).

### *B. Studies for detection of steal*

A group of patients ($n = 14$) was identified by the questionnaire and served as study group. Five individuals had a RC and 9 persons had a BC access. This group was not different from the remainder of the group that experienced steal as determined by the questionnaire with respect to age, gender, diabetes mellitus or access flow (Table 3). It is therefore assumed that the results of measurements obtained from this group of 14 patients is representative of the entire group that reported symptomatology associated with steal ($n = 89$). Results of physical examination are shown in Table 4. Inspection revealed that pallor or cyanosis, trophic lesions or diminished capillary refill were frequently observed in the AVF-hand when compared to the contralateral side (13 vs 5). The radial pulse was less pronounced on the AVF side compared to the healthy arm. Ulnar pulse was decreased on either side, most probably due to its hidden position. Hand temperature, as determined subjectively by the main investigator, was significantly lower on the AVF-side compared to the contralateral hand (Table 5, $p < 0.01$).

Temperatures of the index finger of the AVF-hand were on average 1.0 °C lower compared to the contralateral side (Table 6, $p < 0.02$). Moreover, hand grip strength was approximately 20% lower in the dialysis hand ($17.9 \pm 10.0$ vs $22.2 \pm 11.4$ kg, $p < 0.001$). Finger pressures increased dramatically following compression of the venous portion of the AVF (open: $106 \pm 33$ vs closed $154 \pm 25$, $p < 0.001$). The magnitude of change in finger pressure (in mm Hg) following AVF-compression and access flow (ml/min) were not related. Moreover, no inverse relation was present between absolute values of finger pressures (or DBI), and access flow.

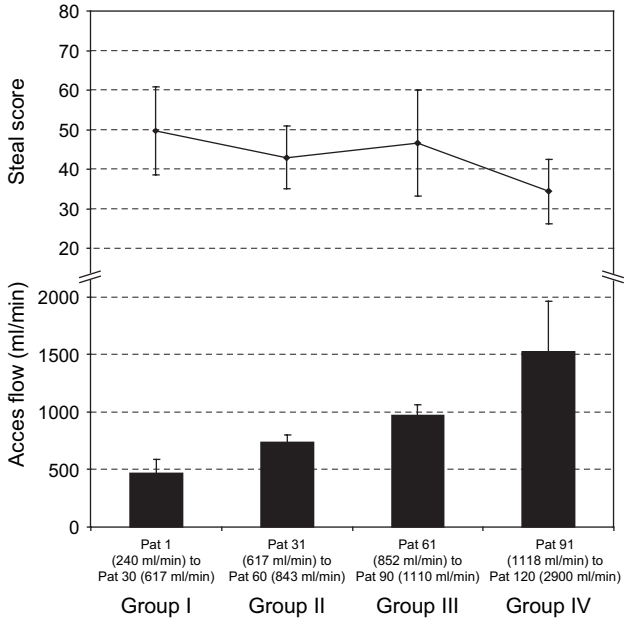


**Fig. 2.** Access flow and steal scores. High access flows were not associated with more intense steal symptomatology as identified by a questionnaire.

**Table 3. Characteristics of subgroup of 14 steal patients that underwent test panel compared to remainder of steal group ($n = 75$, not tested) and group without steal ($n = 31$)**

| | Steal (tested) | Steal (not tested) | No steal | *p* |
|---|---|---|---|---|
| N | 14 | 75 | 31 | |
| Age (y) | $68 \pm 16$ | $66 \pm 13$ | $66 \pm 14$ | 0.51 |
| Male n (%) | 9 (64) | 39 (52) | 19 (61) | 0.40 |
| Diabetes mellitus n (%) | 3 (21) | 12 (16) | 3 (10) | 0.28 |
| AVF flow (ml/min) | $1257 \pm 773$ | $936 \pm 400$ | $853 \pm 526$ | 0.12[a] |

Chi-square.
[a] Univariate Analysis of Variance.

## Discussion

Severe hand ischemia due to steal in the presence of a hemodialysis fistula is considered rare and seldomly requires corrective surgery. The incidence of either severe or mild steal is unknown, since few studies have solely focused on the occurrence of steal phenomena in dialysis patients. Consequently, it is also unclear which factors trigger its onset. In the first month following construction, most AVF's show a reversed direction of blood flow in the distal radial artery. This

**Table 4. Hand inspection in a subgroup of patients on chronic dialysis ($n = 14$) reporting steal**

| Number of patients (%) | AVF arm | Contralateral arm | *p* |
|---|---|---|---|
| Pallor/cyanosis | 6 (43) | 2 (14) | 0.19 |
| Trophic lesions | 4 (29) | 2 (14) | 0.47 |
| Ulcers | 0 (0) | 0 (0) | |
| Capillary refill (>3 sec) | 3 (21) | 1 (7) | 0.59 |
| | 13 (93) | 5 (36) | 0.23 |

Analysis by Chi-square.

**Table 5. Palpation of the dialysis hand in patients ($n = 14$) reporting steal**

| | AVF arm | Contralateral arm | $p$ |
|---|---|---|---|
| Radial artery (0–3)[a] | 2.0 ± 1.2 | 2.9 ± 0.4 | 0.02 |
| Ulnar artery (0–3)[a] | 1.1 ± 1.3 | 1.6 ± 1.1 | 0.28 |
| Diminished sensibility N (%) | 2 (14) | 0 (0) | 0.16 |
| Lower skin temperature N (%) | 7 (50) | 1 (7) | 0.01 |

Wilcoxon Signed Rank Test.
[a] 0 = absent, 3 = normal, see material and methods for explanation.

initial hand hypoperfusion may not be noticed by the patient and usually improves over time.[8–11] If however frank steal symptoms emerge later on, intensity may become more pronounced over time requiring intensive follow-up.[11,12] Interestingly, reversed blood flow in the radial artery may also be present in mature AVF's as demonstrated by Bussel.[3] In contrast, reversed flow in proximal portions of the arterial vasculature such as the brachial artery has not been documented.

Daily practice has unveiled some characteristics of access-induced steal. The incidence of 'late' steal is known to depend on the location of the AVF. For instance, clinically significant steal associated with the presence of a RC fistula is reported in 1.8% of the patients. Moreover, steal in forearm loops and BC fistulas may occur in up to 6% of the population, and between 10–25%, respectively.[8,13–15] The onset of steal is thought to occur more readily in fistulas with large anastomoses and high flows.[16] Generalized arteriosclerotic disease, secondary hyperparathyroidism, carpal tunnel syndrome[17] and neuropathy associated with uremia or diabetes may exaggerate or mimic steal symptomatology.[18–20] For instance, some authors reported that the majority of patients with steal symptoms of the hand following creation of an AVF were diabetic.[9,21] It is unclear whether these comorbid conditions worsen hand ischemia, or only add to its symptomatology since most studies used no objective tools for the measurement of digital hypoxia. In the present study a relationship between diabetes and intensity of steal was observed.

**Table 6. Results of a test panel in patients ($n = 14$) reporting steal**

| | AVF arm | Contralateral arm | $p$ |
|---|---|---|---|
| Blood pressure (mmHg) | | | |
| Brachial artery, systolic | not measured | 155 ± 16 | |
| Brachial artery, diastolic | not measured | 77 ± 13 | |
| Radial artery systolic (Doppler) | 150 ± 59 | 152 ± 28 | 0.78 |
| Ulnar artery systolic (Doppler) | 162 ± 36 | 152 ± 29 | 0.04 |
| Temperature hand (°C) | | | |
| Dorsum | 32.5 ± 1.4 | 32.1 ± 1.6 | 0.40 |
| Palm | 34.3 ± 1.8 | 34.1 ± 1.4 | 0.57 |
| Top dig II | 30.7 ± 2.7 | 31.7 ± 2.6 | 0.02 |
| Oxygenation dig II | | | |
| Saturation (%) | 97.3 ± 1.5 | 96.9 ± 1.1 | 0.29 |
| pO2 (Capillary gas) | 64.1 ± 12.4 | 67.3 ± 8.4 | 0.16 |
| Strength (Kg) | | | |
| Hand grip | 17.9 ± 10.0 | 22.2 ± 11.4 | <0.001 |
| Finger pressure dig II (mmHg) | | | |
| Open AVF | 106 ± 33 | 155 ± 20 | <0.001 |
| Closed AVF | 154 ± 25[a] | | |
| DBI | 0.6 ± 0.3 | 0.9 ± 0.3 | 0.01 |

[a] $p < 0.001$ versus open AVF.
Paired Samples T-Test.

This study systematically investigated incidence of symptomatology traditionally associated with steal in hemodialysis using a novel questionnaire. This study is the first that compares incidence of steal in three different populations of arm accesses. A questionnaire was composed on the basis of an extensive literature search and included questions on incidence, intensity and frequency of steal symptoms. A stable population on chronic dialysis was studied, and a subgroup who reported steal in the questionnaire was selected and underwent measurements using a set of investigational tools. Half of the study population had a RC, whereas one quarter had loops and BC's, respectively. These populations were similar with respect to age, gender, % diabetes and access flow. The results of the questionnaire demonstrated that mild and moderate steal symptoms in each population are experienced on a much larger scale than previously thought. For instance, the RC-group reported steal symptoms to some degree in a frequency ranging from 12% (cold hand) to 25% (pain, cramps, diminished sensibility and weakness). Half of the BC-population complained of a crampy, weak and cold hand. The incidence of steal associated with the presence of a forearm loop was in general similar to the RC-group. The questionnaire also investigated frequency and severity of symptoms in patients that reported steal. If a patient indeed suffers from steal, intensity is not different among the three dialysis populations. In other words, type of AVF does not determine intensity of steal symptomatology. Interestingly, pain was reported of mild intensity (mean VAS was 3.7 on a 0–10 scale). In contrast, weakness was moderate (VAS up to 5.6) and very frequent (7.8).

What are the clinical consequences of these findings? DOQI advocates the construction of a BC as an alternative second choice fistula. It must be realised that this form of dialysis access is more likely

to be associated with steal symptoms. Therefore, if several risk factors for steal are present in the predialysis situation (diabetes, generalized arteriosclerotic disease, hyperparathyroidism), particularly in the presence of low finger pressures, one may consider implanting a prosthetic forearm loop fistula.

A second aim of the study was to perform a pilot study with a set of investigational tools aimed at objectively detecting steal in hemodialysis patients. The questionnaire identified a representative subgroup of 14 patients that experienced steal. Their contralateral arms were used for obtaining control values, thus excluding potential comorbidity as a confounding factor. Simple physical examination revealed the presence of pallor, cyanosis and prolonged capillary refill in some steal hands. Moreover, radial pulses were significantly less prominent on the steal wrist when compared to the contralateral side. This phenomenon may be related to reversed blood flow and a lower vascular peripheral resistance. Although one would expect lower systolic blood pressures in the radial artery, no significant difference was observed compared to pressures on the contralateral side. Testing skin temperature of the dialysis hand as performed by palpation by the principal investigator is considered a rather subjective investigation with obvious limitations. Nevertheless, in half of the patients ($n = 7$) the steal hand was judged cooler compared to only one cold hand on the other side ($p < 0.01$). Therefore, less pronounced arterial pulsations combined with a cooler hand are simple (although subjective) observations and may aid in the diagnosis 'steal' in the presence of a AVF.

Although physical examination is a first and probably subjective step in determining steal in the presence of an AVF, a physician would be greatly aided by an objective test that was able to discriminate between presence or absence of steal. In this study temperatures of both dorsum and palm were not different, but the temperature of the index finger was significantly lower on the dialysis hand. It may well be that this portion of the hand, because of its distal location, is prone to exhibit the consequences of diminished blood flow in an early phase. Capillary blood gas measurements appeared not to help in establishing the diagnosis. Pulse oximetry is reported as a useful diagnostic tool for evaluating oxygenation status and cyanosis distal to an AVF.[22,23] However, in the present study oxygen saturation as measured with oximetry was not discriminative. In concert with others, a lower hand grip strength in the dialysis arm was found. This finding supports data used by DOQI to instruct patients not to carry heavy weights with their dialysis arm.[1] Grip strength is known to fall with increasing age in a nonlinear way. Lower limits of acceptable grip strength are defined as 85% of the normal strength adjusted for age and sex.[24] All steal patients who performed grip strength measurements had values well below this 85% threshold (mean: $53 \pm 5\%$). Surprisingly, also in the non-dialysis hand low values were observed (mean: $68 \pm 6\%$). Only 4 patients had values equal or more than the 85% lower limit ($p < 0.01$). These grip strength measurements indicate that chronic dialysis leads to considerable loss of muscle function in general, and these phenomena may intensify in the presence of steal.

Most authors argue that presence of steal and access flow are related in a direct fashion. The present study did not find this relationship. On the contrary, patients with the highest steal score as determined by the questionnaire showed a trend towards lower access flows when compared to patients that displayed a steal score of nil. Several factors may contribute to explaining this discrepancy. A direct relationship may only be true in high output fistulae but not in medium or small ones as present in our study. Moreover, sensations traditionally associated with the presence of steal (cold feelings, cramps etc) may be caused by a spectrum of factors in which ischemia only plays a limited role. The present study has not looked into the contribution of other factors such as uremic neuropathy or hyperparathyroidism. However, diabetics appeared at risk for steal as demonstrated by other investigators.

Photoplethysmography may be the only investigational tool that is thought to have potential in diagnosing steal in hemodialysis. A ratio of finger to arm blood pressure (DBI, digital-brachial index) of 0.6 is reported as a cut-off point, with a sensitivity for steal of 100%, and a specificity of 63–76%.[5,6] The mean DBI value in our group of patients was 0.6, but a range of 0.44 to 1.08 indicates that even a patient with a high DBI may experience steal. Finger pressure measurements with and without external compression of the AVF revealed that 'closing' of the fistula resulted in a 45% increase in finger pressure ($106 \pm 33$ mm Hg vs $154 \pm 25$ mm Hg) and returned to normal levels similar to the other side ($155 \pm 20$ mm Hg). These results show that each of these AVFs obviously does steal, as determined by photoplethysmographic measurements. Moreover, low finger pressures in patients who subjectively report steal return to normal values following closure of the AVF. Steal in these patients is therefore not fixed but reversible and possibly responsive to corrective surgery if ever required.[4]

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**Appendix-Steal Questionnaire**

A. General information

1. Name, age, sex
2. Type of fistula
3. Date of (last) operation
4. Side
5. Left or right dominance

B. Specific information

Cold sensations

1. Do you experience cold sensations in the fistula arm/hand (if not, go to question 6) ?
2. Which location (lower arm/wrist/hand/fingers) ?
3. Which finger (s) ?
4. Severity of cold sensation (0= no cold sensation, 10= freezing cold) ?
5. Frequency of cold sensation (0= never, 10= always) ?

Minimal = 0, Max = 10 (severity) × 10 (frequency) = 100 points for cold sensation

Pain

6. Do you feel pain in the fistula arm/hand (if not, go to question 11) ?
7. Which location (lower arm/wrist/hand/fingers) ?
8. Which finger(s) ?
9. Severity of pain (0 = no pain,10 = unbearable) ?
10. Frequency of pain (0 = never, 10 = always) ?

Minimal = 0, Max = 10 × 10 = 100 points for pain

Sensibility

11. Is diminished or altered sensibility present in the fistula arm/hand (if not, go to question 14) ?
12. Severity of diminished sensibility (0 = normal sensation, 10 = total numbness) ?
13. Frequency of diminished sensibility (0 = never, 10 = always) ?

Minimal = 0, Max = 10 × 10 = 100 points for altered sensibility

Strength

14. Do you experience diminished strength in the fistula arm/hand (if not, go to question 17) ?
15. Severity of diminished strength (0 = normal strength, 10 = total weakness) ?
16. Frequency of diminished strength (0 = never, 10 = always) ?

Minimal = 0, Max = 10 × 10 = 100 points for strength

Cramps

17. Do you suffer from cramps in the fistula arm/hand (if not, go to question 20)
18. Severity of cramps ( 0= no cramps, 10 = spasms) ?
19. Frequency of cramps (0 = never, 10 = always) ?

Minimal = 0, Max = 10 × 10 = 100 points for cramps

Maximal Steal Score = 500 points

20. Did you notice pallor in the fistula arm/hand: yes/no ?
21. Did you observe changes in nail appearance in the fistula hand: yes/no ?
22. Do you have diminished growth of hair in the fistula arm/hand: yes/no ?
23. Do you suffer from ulcers in the fistula arm/hand: yes/no ?