Prosthetic Hemodialysis Access-induced Distal Hand Ischemia and its Contributors in Diabetics

Abstract
Avoidance of hand ischemia in the construction of prosthetic access for hemodialysis in diabetics that have no suitable vein for arteriovenous fistula is appreciated. Taper type may be an appropriately matched conduit to prevent its occurrence. This is a prospective controlled trial of 38 selected diabetics requiring hemodialysis, who were referred to our clinic during a period of 6 months. The aim of the study was to evaluate the efficacy of tapered grafts in preventing distal hand hypoperfusion and determining its most likely contributors. In 18 intervening cases, taper 4 mm × 7 mm and in twenty cases (control group), standard 6 mm polytetrafluoroethylene as straight Brachial-Axillary access was used. Graft flow rates, artery and vein diameters, and mean arterial pressure were included for evaluation. Within the control group, 11 patients (55%) (7 cases Grade 1, 3 Grade 2, 1 Grade 3) and in intervening group, 2 cases (11%) (Grade 1, Grade 3) developed Steal syndrome. There was no significant difference in the mean flow rates (P = 0.82). Increased risk of distal hypoperfusion was observed in the control group when flow rates were more than 1000 ml/min. Arterial diameters (P = 0.011) and mean arterial pressure (P = 0.05) were found to be important contributing factors. Taper grafts causes reduced incidence of distal hand hypoperfusion. When artery diameter was < 6 mm and mean arterial pressure lower than 100 mmHg and the index (brachial artery diameter × mean arterial pressure) was under 500, distal hand ischemia occurred in standard and taper type. We therefore recommend selective usage of taper grafts in diabetics with diminished distal hand pulses, considering the contributing factors when fistula first is not feasible.

Keywords: Brachial-axillary arteriovenous graft, diabetes, hemodialysis access-induced distal hand ischemia, steal syndrome, tapered graft

Introduction
Since the recommendation of taper type of expanded polytetrafluoroethylene (ePTFE) as a new modality with crucial supporting properties on hemodynamic and flow rate of accesses for dialysis,[1] few studies investigated its efficacy in reducing the risk of hemodialysis access-inducing distal hand ischemia (HAIDI) in diabetics. Simultaneous application of standard ePTFE and its taper kind for comparison is also rare. Those that exist, neither have demonstrated the role of the taper grafts in high-risk patients notably “diabetics,” nor determined their predisposing factors implicated in access producing steal syndrome. In construction of an effective access, brief studies have obtained useful results, but they have more evidently focused on autogenous arteriovenous fistulas (AVF). Fistula first principle has to be followed as far as possible. AV grafts should be reserved only in specific cases, and these should be done by experienced surgeons. Diabetic patients occasionally cannot tolerate long hours of dialysis due to extremity pain; however, without dialysis, patients may face–hand rest pain, defective fingers movement, nail cyanosis, and further numbness. The majority of these are shown to be due to hypoperfusion, which in the existence of previous satisfactory distal hand pulses is referred to as steal phenomenon; though now, there is advocacy that the steal may be a misnomer. On the other hand, in spite of selective application of arteriovenous grafts (AVGs), sometimes, problematic extremities present with distal circulatory deficits due to the impaired arterial flow that can lead to severe pain or even irreparable ischemia. In such circumstances, the choice could either be lower extremity vascular access or utilizing long lasting cuffed catheters. Thus, it is necessary to consider the effective selection, especially in diabetics, old patients and who sustained severe peripheral vascular
disease accompanied by distal circulatory deficit, arterial
strictures, neuropathy, or concomitant myopathy. This study
was aimed to evaluate and compare HAIDI occurrence in
diabetics who had taper and standard ePTFE graft used
for their accesses, considering the existence of their distal
pulses and focused to determine its contributing factors.

Materials and Methods
This was a prospective controlled trial containing 38 diabetic
patients with end stage renal disease (ESRD). Patients
lacked suitable veins for AVF and were all candidates
for construction of prosthetic AVG for hemodialysis.
Patients were referred to our vascular surgery department
doctor Golestan hospital affiliated to Ahwaz Jundishapur
University of Medical Sciences, Ahwaz, Iran. The duration
of the study was from January 2013 to June 2013. The
aims of the trial were to evaluate the efficacy of tapered
grafts in preventing HAIDI and also to identify the most
likely contributing factors during their primary patency.
The trial was registered in Iranian Clinical Trials, No:
IRCT 2013041212993N1. The main subject of the research
article as a thesis has been approved by institutional
research and ethical committee of Jundishapur medical
faculty No: D/552. All patients gave their written informed
consent prior to the commencement of the study. Inclusion
criteria were diabetic patients with clinically nonocclusive
upper extremity arterial status and acceptable good radial
pulses with approved motor-sensory examinations that had
no suitable superficial vein bilaterally for the construction
of AVF and, therefore, were the candidate for prosthetic
brachial-axillary AVG. Exclusion criteria were pulseless
diabetics, history of hand or forearm trauma, orthopedic
surgery on forearm and wrist and candidates for placement
of AVF as the first line and grafts in lower extremities.
Patients were routinely selected by accurate clinical
examination that was able to demonstrate good projection
of dominant veins and for others who clinically were not
clear, including the obese and previous thrombosed AVF,
venous mapping with color Doppler was used to confirm
their lack of suitable venous mapping and rejecting
AVF construction. From 38 cases that were entered into
the study, twenty patients were control group in whom
straight standard 6 mm ePTFE were used with the mean
age of 59.3 years (42–84), 13 (65%) female and 7 (35%)
males. Other intervening group was 18 males. Other
intervening group was 18 patients in whom short taper ePTFE 4 mm × 7 mm grafts were used with
the mean age of 56.06 years (31–79), 12 (66%) female and 6 (34%) male. Straight standard 6 mm and short
taper 4 mm × 7 mm AVG were constructed individually
and one by one intermittently at random. Similarly, up to
7 mm arterial orifices for arterial-graft anastomosis and at
least 4–5 cm length for tapering distance were considered.
All the grafts were provided in their non-dominant arm
in the form that grafts were over sewn to brachial artery
in above the elbow crease (cubital fossa) and axillary
vein in the beginning of sub axillary fossa, by a vascular
surgeon. Diameters of brachial arteries and axillary
veins were measured by using metallic sterile bi-side pin
compass and a concomitant metallic sterile ruler before
any releasing to avoid vessel spasm. The mean arterial
pressure was checked during the operation and recorded.

In recovery room, the flow rate in proximal and distal side
of grafts were measured and recorded by portable digital
color Doppler ultrasound, SonoScape S6 machine and by
the same operator in all patients. The next day and then
on daily basis, all the patients were re-examined for any
symptom or sign of distal hand hypoperfusion until they
were discharged. We have used arterial site compression test
clinically for determining any steal producing pulselessness
for hand ischemia, if it was presented by the patients.
The mild to moderate ischemic presentation was followed
until recovery along with finger exercise or any further
requiring open surgical (drill procedure) or percutaneous
interfering repair up to primary patency period. In the
2nd week post-construction, patients started hemodialysis
from grafts with permission. The recorded data and
results were statistically analyzed and interpreted by SPSS
version 20.0 (IBM, Armonk, NY, USA).

Results
All patients had diabetic kidney disease as the cause of
ESRD and had good radial pulses. Some had history of
ischemic heart disease, hypertension, stroke, intermittent
claudication and neuropathy, and a few cases had distal
hand muscle atrophy. Results of comparing the two groups
are depicted in Table 1.

Eleven patients (55%) from control group (standard graft)
eventually developed HAIDI. Seven cases (35%) were
mild form (Grade 1), 3 (15%) moderate (Grade 2), and
1 (5%) severe (Grade 3) that warranted intervention for
limb salvage by DRIL procedure. Within the 18 cases of
trial group (tapered graft), only two cases (11%) developed
steal, one of them in the Grade 1, and the other in Grade 3
who also was repaired by DRIL operation. No percutaneous
intervention was performed.

The mean outgoing blood flow rate of graft circulation was
973.25 ml/min (560–1550) in control standard group and
992.35 ml/min (550–1600) in taper graft group, respectively.
There was also an increased risk of hand ischemia in flow
rates higher than 1000 ml/min in control group, which was
not observed in the taper group; however, this effect did not
reach statistical significance (P = 0.82) [Figure 1]. Although
similar, high flow rates are associated with increased risks
of cardiac complications, the observed high flow rate did
not cause any such effects. Of note, cardiac complications
are not usually produced in flow rates <1500–1700 cc/min
in normo-cardiac uremic patients unless in previously
cardiac myopathic involvement or severe uremic lungs
and hearts and elongates years for new dialysis patients to
present.

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According to the measurements of brachial arteries and axillary veins, the mean diameter of brachial arteries was 5.35 mm (4–8) and 4.55 mm (3–6) in the control and taper groups, respectively. Interestingly, statistically significant increased risk of HAIDI was found in arterial diameter <6 mm in standard control group (P = 0.011). However, this was not observed in intervening taper group [Figure 2].

The mean diameter of axillary vein before and after the venous valve was 7.40 mm in control group and 6.76 mm in the taper group. There was no correlation between the aforementioned diameters and HAIDI.

The mean arterial pressure was 101.60 mmHg (70–140) for control patients and 112.76 mmHg (78–133) for constructed taper grafts. Analysis has shown a significant increase in risk of HAIDI (P = 0.050) with mean arterial pressure lower than 100 mmHg in both groups [Figure 3].

Since both brachial artery diameters and mean arterial pressure have reverse correlation with the risk of hand ischemia, we used multiplication of these two parameters as a new suggested index and found that this index predicted statistically significant correlation with the risk of HAIDI occurrence (P = 0.05). If millimeters were used for the diameter and mmHg for the pressure, the threshold of significant HAIDI will be approximately “600” for standard 6 mm diameter and “500” for tapered 4 × 7 grafts, [Figure 4].

There were no correlations between other demographic parameters such as sex, age, radial pulse existence, severity or the duration of involving diabetes, hypertension, ischemic heart disease, previous stroke, and intermittent claudication with developing HAIDI in the study. Long-term patency and risk of thrombosis were not evaluated in this study.

Discussion

HAIDI is caused by multi-factorial complex phenomena. Some of its causes have been recognized in literature. Utilizing synthetic grafts;[2] old age patients, especially those with large bores graft access;[3,9] autogenous upper arm brachial-based AVFs in late chronic phase;[4,5] diabetes ground;[2,3] reduction in forearm arterial blood and bed pressure by high outflow exhaust through the graft or physically, turbulent flow at the arteriovenous anastomosis site;[6–8] side venous branches in AVFs;[9] severe peripheral arterial disease;[5,8,9] preoperative high digital-brachial index (DBI <0.45–1.0),[6,10] and iatrogenic occurrence[11] are all previously known contributing factors for Steal development. The incidence of symptomatic Steal with hand ischemia ranges from 0.5% up to 28%.[3,4,7,9] Based on geometry and physiologic causes, mean access flow, mean arterial pressure, and digital-brachial index may also be implicated in Steal syndrome. On the other hand, multiple native interfering parameters may accelerate Steal producing with hand ischemia and fix it as a progressive syndrome. Accordingly, loss of propagating circulatory stream, overwhelming thrombosis induced by hypercoagulable state, and low arterial pressures due to severity of atherosclerosis in diabetic patients have been accounted.

Diabetics, who suffer from ESRD and require vascular access for hemodialysis, characteristically, possess these susceptibilities. To handle these propensities, close clinical management and practical procedure individualization are required. Presumably now, presence of hand ischemia in patients is correctly being handled by selecting the procedure, and the technique besides predicting its probability that provoke less complications and succeeding in more efficient access constructions. Clinical selection and physical examination are enough for the risk prediction in all patients; since, competent studies have shown minor contradictions in their findings. Nonsignificant and similar geometric results in comparisons,[12,13] wide range of DBI with lack of definite threshold even for inevitability,[5,6,10] and overall, inexistence of certain acceptable index for accurate case selection, are the examples.

According to our findings, in diabetic group with taper access, the flow rates were identical in comparison with

| Variables                        | Groups      | Mean     | SD       | n  | df | t, significant | P       |
|----------------------------------|-------------|----------|----------|----|----|----------------|---------|
| Brachial artery (D)              | Taper       | 4.55     | 0.862    | 18 | 35 | 1.469          | 0.011   |
|                                  | Control     | 5.35     | 1.182    | 20 |    |                |         |
| Axillary vein (D)                | Taper       | 6.76     | 1.985    | 18 | 35 | 1.790          | 0.262   |
|                                  | Control     | 7.40     | 1.392    | 20 |    |                |         |
| Flow rate (cm/s)                 | Taper       | 992.35   | 279.849  | 18 | 35 | 1.711          | 0.828   |
|                                  | Control     | 973.25   | 249.849  | 20 |    |                |         |
| MAP                              | Taper       | 112.76   | 13.980   | 18 | 35 | 1.981          | 0.058   |
|                                  | Control     | 101.60   | 19.616   | 20 |    |                |         |
| MAP × D artery index             | Taper       | 491.71   | 120.008  | 18 | 35 | 1.991          | 0.050   |
|                                  | Control     | 593.60   | 174.305  | 20 |    |                |         |

In the table, P values demonstrate that there were significant differences in diameters, mean arterial pressures, and new extracted index defined as MAP × arterial diameter, were achieved in comparison between taper group (n=18) and controlled group (n=20). Venous diameters and flow rates had not any difference. Lack of flow rates difference express the efficiency of taper type function parallel to standard grafts.

MAP: Mean arterial pressure, SD: Standard deviation.

Variables Groups Mean SD n df t, significant P

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control standard grafts, similar to attained results of Van Tricht et al., expressing that the taper distance did not affect the flow. Furthermore, acquired significant efficacy of taper graft to prevent Steal complication (11%, compared to 55% overall incidence in standard type) demonstrates its preference to standard type in our cases. In conformity to literature, presumably, “tapered distance” possesses a considerable physical property to block the establishment of turbulent flow in proximal anastomosis compared to standard type. Moreover, it has been postulated that appropriate tapering of graft diameter in constructing an access is able to reduce higher pressure at the narrow segment of arterial side anastomosis and abolish the turbulent anastomotic vortex which is responsible for both high pressure arterial flow outgoing and low pressure distal circulation defined as Steal syndrome. Having considered this issue, Van Tricht et al. have also shown that the pressure drop at the arterial anastomosis site of tapered 4 mm × 7 mm graft, is three times higher than in 6 mm straight graft model in spite of no statistically significant differences between geometries. Concomitantly, Krueger et al. have shown a statistically significant reduction in flow rate up to 28% in 4 mm and up to 55% in 3 mm of narrow segments. Upon these facts, the acceptance of taper graft efficiency
for controlling the Steal syndrome and producing HAIDI, have been confirmed.

Nevertheless, according to statistical analysis, we believe that all the above-mentioned explanations are not purely denoting on tapered zone as demonstrated by further correlations between Steal and the diameters of brachial arteries and the mean arterial pressure that were achieved within control group. These findings can be interpreted as Steal contributing factors that with the existence of narrow artery of <6 mm, arterial pressure <100 mmHg, and flow rate more than 1000 ml/min, the steal concomitant with distal hand ischemia would be mostly possible. Hence, based on correlations, the achieved mean brachial artery diameter (5.35 mm) in control group of standard grafts might account a relevant contributor for the high rate of 55% steal occurrence with 35% Grade 1, and the two other cases of Grade 3 in both groups in spite of identical arterial orifice for anastomosis. Of note, in taper group, there was no such statistical difference. However, we believe one exception exist against the low diameter effect on producing Steal syndrome. That is the anatomically bifurcated brachial artery in upper arm. Although in patients with divided artery in upper arm diameter of branches may be < 5–6 mm, to have confidence that both distal arteries are palpable or their circulation are being confirmed by Allen’s test, HAIDI will not be expected to occur.

Totally, although we believe that taper type graft was useful in preventing HAIDI occurrence in our selected diabetic cases, we do not advocate free usage of this type of grafts in all nondiabetic population demanding prosthetic dialysis access or other diabetics who have normal distal hand arteries and pulses, since the early outcomes of two kinds of grafts in our study and also secondary late outcome in others were similar. On the other hand, most of nondiabetic or diabetic patients with normal pulse do not develop hand ischemia or may experience mild form (Grade 1), which resolves spontaneously.

Consequently, based on our observations, we recommend that tapered grafts could be an ideal access in selected diabetic patients who have diminished distal pulses or narrow brachial artery, otherwise standard grafts may be utilized. Generally, we warn if in diabetic patients brachial artery is narrower than 6 mm, mean arterial pressure is lower than 100 mmHg and if the index: “the multiply of diameter to pressure” is below than 500; then, utilizing any type of grafts may produce mild to perhaps more severe HAIDI. Whereas in patients with index value >500, the risk of threatening or significant ischemia is low and any kind of standard grafts may be safely used. Available Doppler is the accepted method and complements for the evaluation of population with renal insufficiency, especially diabetics before any access construction.

Our studies offer alternative strategy in treating diabetics with secondary vascular complications. Diabetes is a major cause of death worldwide that is associated with secondary health complications. The incidents of diabetes are rapidly increasing worldwide, and the rates are particularly high in the Middle East and South Asia. Our observations were made within a cohort of Iranian patients population. However, this research outcome can directly be implemented in existing Indian patient population suffering from complications associated with diabetes and provide alternative strategies in clinical care in patients with specific vascular implications. Without any limitation, further investigations with larger populations and long-term follow-up are recommended to support our findings and find the new correlations.

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Conflicts of interest
There are no conflicts of interest.

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