PHOTOPLETHYSMOGRAPHY and Digital Pressure

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Disclosure

Speaker name: Gilbert FRANCO

I have the following potential conflicts of interest to report:

☐ Consulting
☐ Employment in industry
☐ Shareholder in a healthcare company
☐ Owner of a healthcare company
☐ Other(s)
☒ I do not have any potential conflict of interest
HEMODYNAMIC EFFECT OF AVF

Vascular access leads to significant hemodynamic changes

Low-resistance short circuit through the shunt

↓

Absolute blood flow is increased

↓

BUT DRIVE

To a net reduction of blood flow to the fingers

WITH

10 to 20% of ISCHEMIC STEAL

AND

4% NEEDS REINTERVENTION

Hubert TS, Access-related hand ischemia and the Hemodialysis Fistula Maturation Study. J. Vasc Surg 2016
Diagnosis is sometimes difficult:
Neurologic disease may closely simulate vascular disease and they could co-exist

Positive diagnosis
Choice of treatment

Should be based on functional and anatomic evaluation

EBPG on Vascular Access (2007)

Guideline 9.1. Access-induced ischaemia should be detected by clinical investigation and the cause should be identified by both non-invasive imaging methods and angiography (Evidence level III).

Guideline 9.2. Enhancement of arterial inflow, access flow reduction and/or distal revascularization procedures are the therapeutic options. When the above methods fail, access ligation should be considered (Evidence level II).
HEMODYNAMIC PERTURBATIONS AFTER AVF PLACEMENT

AVF results in a mean:
- Pressure drop of 30 mm Hg
- DBI drop of 15%

<table>
<thead>
<tr>
<th></th>
<th>AVF</th>
<th>OPPOSITE</th>
</tr>
</thead>
<tbody>
<tr>
<td>P DIGIT (mm Hg)</td>
<td>99</td>
<td>128</td>
</tr>
<tr>
<td>DBI</td>
<td>0.77</td>
<td>0.89</td>
</tr>
</tbody>
</table>

PERSONAL DATA 2013
TANAKA A J vasc Access 2014
Combination of the three mechanisms can lead to peripheral ischemia

- Retrograde flow +/- High flow
- Inflow stenotic lesions
- Distal arteriopathy

**DIGITAL PRESSURE DROP**

- Konner K. Kidney Int 2002
- Sivanesan S. Nephrol Dial Transplant (1998)
- Berman SS. J Vasc Surg 1997
- Schanzer HJ. Vasc Surg 1992
DIGITAL PRESSURE MEASUREMENT

COMPLETE AND FOLLOWS DUPLEX_SCAN

- ISCHEMIC RISK MANAGEMENT PRIOR TO AVF CREATION
- POSITIVE and DIFFERENTIAL DIAGNOSIS of HAIDI
- TEST THERAPEUTIC OPTIONS
- CONTROL OF EFFICIENCY

EBPG on Vascular Access
Guideline 9.1.
Access-induced ischaemia should be detected by clinical investigation and the cause should be identified by both non-invasive imaging methods and angiography. Nephrol. Dial. Transplant. (2007)
Thresholds

40-15 mm Hg

Critical closing pressure: variable with tonus
40-15 mmHg

Hypoxia under this threshold

30 mm Hg

Critical ischemia

55 mm Hg

Condition of healing

Healing unlikely if toe pressure < 55 mmHg
NON INVASIVES TOOLS

- Plethysmography/Photoplethysmography
- Nailfold Capillaroscopy
- Laser Doppler blood perfusion imagers
- Laser Doppler measurements
- Oxymetry: tcpo2 / sao2
- Thermography
PHOTOPLETHYSMOGRAPHY (PPG) OPERATING METHOD

- Light from LED is directed towards the skin where it is absorbed and scattered in tissues
- Detect blood volume changes in the microvascular bed
- Photosensor is placed on the distal pad of the finger detects the backscattered light
- Occlusion cuff inflated automatically is wrapped on the proximal part of the finger
- Deflated slowly at a controlled rate.
- During deflation, resumption of blood flow downstream from the cuff is detected by the PPG sensor
PRESSURE MEASUREMENTS
PRIOR VASCULAR ACCESS CONSTRUCTION

- (BDP) : BASAL DIGITAL PRESSURE: SEVERITY OF PERFUSION DEFICIT
- (DBI) : DIGITAL BRACHIAL INDEX: < 0.7
  SENSITIVITY 90/100% TO POSTIVE DIAGNOSIS OF PAOD
- ALLEN’S TEST WITH US AND DIGITAL PRESSURE MESUREMENT
  IN CASE OF AVF AT WRIST
COMPRESSION TEST
PRIOR AVF CREATION or DRAL
ALLEN’S TEST WITH US AND DIGITAL PRESSURE MESUREMENT

RA Compression

Color Doppler of palmar artery Occlusion of radial artery while imaging arch Reversed flow Flow via ulnar artery

US may improve accuracy of Allen’s test
First reported in 1973


PATENCY of UA and PALMAR ARCH

Ulnar Artery is the Key Stone of HF HAID1
PREDICTION OF HAIDI

MUST BE FOCUSED ON PREDICTION OF STAGE 3 AND 4
Do preoperative finger pressures predict early arterial steal in hemodialysis access patients? A prospective analysis

R. James Valentine, MD, Charles W. Bouch, MD, Daniel J. Scott, MD, Shujun Li, MD, Mark R. Jackson, MD, J. Gregory Modrall, MD, and G. Patrick Clagett, MD, Dallas, Tex

Background: Hand ischemia resulting from arterial steal is a serious complication in patients undergoing hemodialysis access, but specific risk factors for steal remain in dispute. The purpose of this study was to determine whether plethysmographically derived finger pressures (FPs) or digital-brachial indices (DBIs) are predictive of symptomatic arterial steal.

Methods: We prospectively studied 72 patients (37 men, 35 women; mean age, 57 ± 10 years) who were undergoing brachial artery–based hemodialysis access. All patients had complete pre- and postoperative hand examinations and FP determinations. Surgeons were blinded to preoperative FP results.

Results: Prosthetic graft was used in 60 patients (6-mm polytetrafluoroethylene [PTFE] in 50, tapered PTFE in 10), and brachial-based arteriovenous fistulas were created in 12. Fourteen (19%) patients developed arterial steal symptoms. The mean preoperative FP was significantly lower in steal patients than in those without steal (131 ± 27 vs 151 ± 31 mm Hg, P < .02). Nine (64%) of the patients with steal had DBIs <1.0, compared to 18 (31%) of the patients without steal (P = .02). However, there was no absolute FP or DBI threshold below which steal was inevitable. The occurrence of steal was attributed to proximal arterial stenoses in seven, to distal arterial disease in five, and was unknown in two. When comparing the 14 patients who developed steal to the 58 who did not, we noted that a higher proportion of steal patients had coronary artery disease (57% vs 17%, P = .005). Steal was more likely to develop in patients with arteriovenous fistulas than in patients with prosthetic grafts (43% vs 14%, P = .009). There were no significant differences in demographic factors, atherosclerotic risks (diabetes, smoking, hypertension, dyslipidemia), prevalence of peripheral vascular disease, cerebrovascular disease, shunt location, tapered vs straight graft, or number of prior grafts placed.

Conclusions: These data indicate that preoperative FP or DBI is lower in patients who develop steal syndrome after hemodialysis access. Patients with preoperative DBI <1.0 are more likely to develop steal, but there is no DBI threshold below which steal is inevitable. Steal is more likely to develop in patients undergoing brachial-based arteriovenous fistulas than in those receiving prosthetic grafts. (J Vasc Surg 2002;36:351–6.)
Prediction of arteriovenous access steal syndrome utilizing digital pressure measurements

Papasavas PK¹, Reifsnyder T, Birdas TJ, Caushaj PF, Leers S.

Abstract

Steal syndrome is a well-known complication of arteriovenous (AV) access placement. To assess the derangement in hemodynamics of the upper extremity after AV access creation, brachial and digital pressures were performed before and after operation. Thirty-five patients (ages 20-88 years) with end-stage renal disease requiring new upper extremity hemodialysis AV access were prospectively evaluated. Values were obtained preoperatively, on the day of surgery, and 1 month postoperatively. Follow-up at 1 year was obtained on all patients. Of the 35 patients, 19 (54%) were diabetic and 9 (26%) had had a prior AV access. The AV accesses created included the following: autogenous brachial-cephalic (n = 14, 40%), autogenous radial-cephalic (n = 10, 29%), brachial-basilic transposition (n = 5, 14%), prosthetic brachial-antecubital forearm loop (n = 3, 9%), autogenous brachial-axillary saphenous vein translocation (n = 2, 6%), and 1 (3%) prosthetic brachial-axillary. After AV access creation the digital brachial index (DBI) dropped in 28 (80%) of the 35 patients. Six patients (17%) developed a symptomatic steal, 3 of which (9%) eventually required revision. In those patients without ischemic steal symptoms (n = 29) the mean DBI decreased from 0.9 to 0.7 (p < 0.01) immediately and decreased no further at 1 month. For those with a symptomatic steal the DBI decreased from 0.8 to 0.4 (p < 0.01) immediately and decreased no further at 1 month. Utilizing a DBI less than 0.6, the sensitivity was 100%, the specificity 76%, the positive predictive value 46%, and the negative predictive value 100%. Hemodynamic steal after AV access creation is very common, with symptomatic steal occurring nearly a fifth of the time. Utilizing digital pressure measurements a DBI less than 0.6 obtained on the day of surgery can reasonably predict which patients are at risk for the development of a symptomatic steal.
Steal syndrome complicating hemodialysis access procedures: can it be predicted?

Goff CD, Sato DT, Bloch PH, DeMasi RJ, Gregory RT, Gayle RG, Parent FN, Meier GH, Wheeler JR.

Abstract

The development of steal syndrome distal to an arteriovenous fistula (AVF) created for hemodialysis access remains a significant clinical problem. This study was undertaken to determine the role of intraoperative noninvasive testing in the prediction and management of steal syndrome following arteriovenous fistula creation. First, in order to determine a threshold digital/brachial index (DBI) for patients at risk for steal syndrome, we performed a retrospective review of patients who had the DBI measured and who developed symptoms (steal syndrome) following AVF creation. This was followed by a prospective evaluation of the ability of the DBI to predict which patients undergoing AVF surgery would develop steal syndrome. A DBI of <0.6 identifies a patient at risk for steal syndrome. Intraoperative DBI cannot be used to predict which patient will develop steal syndrome; however, if revision is indicated, the DBI should be increased to >0.6. Failure to accomplish this puts the patient at risk for continued steal syndrome.
Access induced ischemia is an uncommon but devastating complication for patients maintained on hemodialysis. A number of clinical risk factors have been identified to select patients at risk. Intraoperative measurement of the digital–brachial index may further distinguish at-risk patients when the DBI is <0.45. Once clinically significant steal has developed, surgical strategies to treat this problem should ideally reverse the ischemia while maintaining uninterrupted access for hemodialysis. To date, the distal revascularization–interval ligation or DRIL procedure has been the most consistently successful tactic in achieving these dual objectives. A number of alternative strategies have recently been proposed and will be discussed.
## CORRELATION BDP/DBI/BP

<table>
<thead>
<tr>
<th>BLOOD PRESSURE mm Hg</th>
<th>BDP mm Hg</th>
<th>DBI</th>
<th>BDP mm Hg</th>
<th>DBI</th>
</tr>
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<tbody>
<tr>
<td>180</td>
<td>60</td>
<td>0.33</td>
<td>126</td>
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<td>170</td>
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<td>150</td>
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<td>120</td>
<td>60</td>
<td>0.5</td>
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<td>0.7</td>
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<tr>
<td>110</td>
<td>60</td>
<td>0.54</td>
<td>77</td>
<td>0.7</td>
</tr>
<tr>
<td>100</td>
<td>60</td>
<td>0.6</td>
<td>70</td>
<td>0.7</td>
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</table>
PREDICTION and PREVENTION OF HAIDI PRIOR CREATION

DBI<0.7
BEFORE CREATION

BDP
AFTER CREATION

BDP
AFTER CREATION

AVF CREATION:
PRESSURE DROP
30 mmHg

60mmHg

PATIENT SAFETY SHOULD BE A MAJOR CONCERN TO AVOID THIS DISASTER
ISCHEMIC RISK and STRATEGIES PRIOR TO CREATION
FOREARM ARTERY STENOsis and / or OCCLUSION

DISTAL RA STENOsis
UA : OCCLUSION

LOW DIGITAL PRESSURE

AVF WRIST
  - FTM
  - HAIDI
  - PTA CLOSURE DISTAL DRIL

AVF ELBOW
  - MAT
  - HAIDI
  - DRIL
DIGITAL PRESSURE
AFTER
VASCULAR ACCESS CREATION
PRESSURE MEASUREMENTS

- (BDP) : BASAL DIGITAL PRESSURE
- (DBI) : DIGITAL BRACHIAL INDEX
- (CDP) : CHANGE IN DIGITAL PRESSURE UNDER COMPRESSION: WITNESS OF IMPORTANCE OF STEAL

WITH ACCESS COMPRESSION

WITH DISTAL RADIAL COMPRESSION (fav at wrist) STOREY?

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# Digital Pressure After Creation

<table>
<thead>
<tr>
<th>AUTHORS</th>
<th>BDP mm Hg</th>
<th></th>
<th></th>
<th></th>
<th></th>
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<td></td>
<td>S</td>
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<td>S</td>
<td>p</td>
<td>AS</td>
<td>p</td>
<td>S</td>
<td>p</td>
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<tr>
<td>Papasavas PK 2003</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0,4</td>
<td>0,01</td>
<td>0,7</td>
<td>0,01</td>
<td></td>
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<tr>
<td>Schanzer A 2006</td>
<td>30</td>
<td>0,01</td>
<td>102</td>
<td>0,01</td>
<td>0,3</td>
<td>0,001</td>
<td>0,8</td>
<td>0,001</td>
<td>85</td>
<td>0,001</td>
<td>40</td>
<td>0,001</td>
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<tr>
<td>Vaes RH 2013</td>
<td>22 +/-10</td>
<td>0,1</td>
<td>102 +/-10</td>
<td>0,1</td>
<td>0,18</td>
<td>0,08</td>
<td>0,1</td>
<td>0,7</td>
<td>0,08</td>
<td>0,1</td>
<td>46</td>
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<td>Modagheh MH 2014</td>
<td>61 +/-26</td>
<td>0,01</td>
<td>114 +/-38</td>
<td>0,01</td>
<td>0,44</td>
<td>0,16</td>
<td>0,01</td>
<td>0,82</td>
<td>0,19</td>
<td>0,01</td>
<td>57</td>
<td>0,01</td>
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<tr>
<td>Journet J 2012</td>
<td>99 +/-32</td>
<td></td>
<td></td>
<td></td>
<td>0,72</td>
<td>+/-23</td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

**BDP mm Hg**

- **S**: Sample size
- **p**: Probability

**DBI**

- **S**: Sample size
- **p**: Probability

**CDP mmHg**

- **S**: Sample size
- **p**: Probability
# POSITIVE DIAGNOSIS OF HAIDI

<table>
<thead>
<tr>
<th>BP</th>
<th>DBI:0.6 BDP</th>
<th>DBI:0.4 BDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>180</td>
<td>106</td>
<td>72</td>
</tr>
<tr>
<td>170</td>
<td>102</td>
<td>68</td>
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<td>90</td>
<td>54</td>
<td>36</td>
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<table>
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<tr>
<th>ACCUR</th>
<th>SENS</th>
<th>SPEC</th>
</tr>
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<tbody>
<tr>
<td>BDP &lt;60mm Hg</td>
<td>92%</td>
<td>100%</td>
</tr>
<tr>
<td>DBI&lt;0.6</td>
<td>92%</td>
<td>100%</td>
</tr>
<tr>
<td>DBI&lt;0.4</td>
<td>94%</td>
<td>92%</td>
</tr>
</tbody>
</table>

Papasavas PK, *Vasc Endo Surg* 2003
Vaes RH, *JVS* 2013
Modaghegh MH, *JVS* 2014

www.cacvs.org
BDP significantly decreased on both sides during dialysis.

Brachial pressure decrease was correlated with the decrease of digital pressure IN BOTH HANDS.

BDP was less than 30 mm Hg in six patients (12%) without ischemia (silent ischemia related to neuropathy?)

VanHoek F, Nephrology (Carlton) 2010
Journet J, J Mal Vasc 2012
Differential Diagnosis of Ischemic Pain

- **Rest Pain**
  - BDP: 83 mm Hg
  - BDI: 0.7

- **Non Ischemic Pain**
The Society for Vascular Surgery Lower Extremity Threatened Limb Classification System: Risk stratification based on Wound, Ischemia, and foot Infection (WIfI)

Joseph L. Mills, Sr, MD, a Michael S. Conte, MD, b David G. Armstrong, DPM, MD, PhD, a Frank B. Pomposelli, MD, c Andres Schanzer, MD, d Anton N. Sidawy, MD, MPH, e and George Andros, MD, f on behalf of the Society for Vascular Surgery Lower Extremity Guidelines Committee, Tucson, Ariz; San Francisco and Van Nuys, Calif; Brighton and Worcester, Mass; and Washington, D.C.

Critical limb ischemia, first defined in 1982, was intended to delineate a subgroup of patients with a threatened lower extremity primarily because of chronic ischemia. It was the intent of the original authors that patients with diabetes be excluded or analyzed separately. The Fontaine and Rutherford Systems have been used to classify risk of amputation and likelihood of benefit from revascularization by subcategorizing patients into two groups: ischemic rest pain and tissue loss. Due to demographic shifts over the last 40 years, especially a dramatic rise in the incidence of diabetes mellitus and rapidly expanding techniques of revascularization, it has become increasingly difficult to perform meaningful outcomes analysis for patients with threatened limbs using these existing classification systems. Particularly in patients with diabetes, limb threat is part of a broad disease spectrum. Perfusion is only one determinant of outcome, wound extent and the presence and severity of infection also greatly impact the threat to a limb. Therefore, the Society for Vascular Surgery Lower Extremity Guidelines Committee undertook the task of creating a new classification of the threatened lower extremity that reflects these important considerations. We term this new framework, the Society for Vascular Surgery Lower Extremity Threatened Limb Classification System. Risk stratification is based on three major factors that impact amputation risk and clinical management: Wound, Ischemia, and foot Infection (WIfI). The implementation of this classification system is intended to permit more meaningful analysis of outcomes for various forms of therapy in this challenging, but heterogeneous population. (J Vasc Surg 2014;59:220-34.)
Society for Vascular Surgery Lower Extremity Threatened Limb (SVS WIFI) classification system

I. Wound
II. Ischemia
III. Finger Infection

<table>
<thead>
<tr>
<th>Grade</th>
<th>DBI</th>
<th>Ankle systolic pressure</th>
<th>DP TcPO$_2$</th>
</tr>
</thead>
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<tr>
<td>0</td>
<td>≥0.80</td>
<td>&gt;100 mm Hg</td>
<td>≥60 mm Hg</td>
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<td>1</td>
<td>0.6-0.79</td>
<td>70-100 mm Hg</td>
<td>40-59 mm Hg</td>
</tr>
<tr>
<td>2</td>
<td>0.4-0.59</td>
<td>50-70 mm Hg</td>
<td>30-39 mm Hg</td>
</tr>
<tr>
<td>3</td>
<td>≤0.39</td>
<td>&lt;50 mm Hg</td>
<td>&lt;30 mm Hg</td>
</tr>
</tbody>
</table>

Estimate risk of amputation at 1 year for each combination

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PRESSURE MEASUREMENTS with COMPRESSION and CHOICE of TREATMENT

CHANGE IN DIGITAL PRESSURE (CDP): WITH ACCESS COMPRESSION

- WITNESS OF THE RELATIVE IMPORTANCE OF STEAL COMPARED WITH ARTERIAL LESIONS
- IF BDP INCREASES ABOVE ISCHEMIC THRESHOLD UNDER ACCESS COMPRESSION
  INTERVENTION TARGETTING STEAL IS INDICATED: FLOW REDUCTION (If High Flow) DRIL / PAVA / PAI

CHANGE IN DIGITAL PRESSURE (CDP): WITH DISTAL RADIAL COMPRESSION

- IF BDP INCREASES ABOVE ISCHEMIC THRESHOLD UNDER DISTAL RADIAL COMPRESSION
  INTERVENTION TARGETTING STEAL IS INDICATED: DRAL

- FOR THOSE PATIENTS WHO DO NOT MEET THESE THRESHOLDS
  SURGICAL INTERVENTION AIMED AT REVERSING THE STEAL IS NOT THE APPROPRIATE TREATMENT

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CONCLUSION

- Digital pressure measurement despite some limitation and scepticism is helpful
- Complete physical examination
- Complete Duplex-scan
- Providing objective data
- Help management of HAIDI

- Why is it underused?
- What hematologist will be satisfied with the white of the eye and give up blood tests?

However
Randomized trials on HAIDI are still lacking and should be designed

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THANKS FOR YOUR ATTENTION
ANY QUESTIONS?