Treatment of vascular steal syndrome

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Author: Christine Russell

GUIDELINES

No recommendations possible based on Level I or II evidence

SUGGESTIONS FOR CLINICAL CARE
(Suggestions based on level III and IV evidence)

- Patients with symptoms of steal should be investigated for inflow stenosis.
- There are a number of surgical procedures that can be used in the treatment of steal – Distal revascularisation interval ligation (DRIL) procedure is probably the most widely used and durable, with preservation of the access.

IMPLEMENTATION AND AUDIT

Audit the number of patients developing steal syndrome, interventions and patient outcomes.

BACKGROUND

Patients with steal phenomenon can present with paraesthesia, pain, ulceration and tissue loss. Some degree of steal is common, for example, in a questionnaire of 120 haemodialysis patients, 50% of patients with a brachio-cephalic AVF reported a cold hand compared with 12% of those with a radio-cephalic AVF [1]. Dialysis Access Steal Syndrome (DASS) requiring intervention has an incidence of around 4%, although 10-20% of patients with AV fistulas or grafts may suffer some degree of ischaemia causing pain or paraesthesia [2]. DASS tends to present earlier in patients with an AV graft (AVG) compared to those with a native AV fistula (AVF). For example the study by Lazarides et al [3] reported an average time interval from access construction to occurrence of DASS of 2 days for AVG’s and 165 days for AVF’s.

DASS is usually due to one or more of the following factors:
- Inflow stenosis – defined as stenosis within the arterial system, artery-graft anastomosis (graft cases), artery-vein anastomosis (fistula cases) and juxta-anastomotic region (the first 2 cm downstream from the arterial anastomosis)[4]
- Retrograde flow – back flow into the artery distal to the arteriovenous anastomosis and into the arteriovenous access [5]
- Distal arteriopathy – result of generalized vascular calcification due to diabetes [6]

It may also rarely be due to a high flow fistula in patients with otherwise normal vessels [2].

A grading scheme has been proposed by Sidaway et al [7].

- Grade 0: No steal
- Grade 1: Mild - cool extremity with no symptoms but steal demonstrated by flow augmentation with access occlusion.
- Grade 2: Moderate - intermittent ischaemia only during dialysis/claudication
- Grade 3: Severe - ischaemic pain at rest/tissue loss

Alternatively the leg ischaemia grade has been proposed by Tordoir et al [8].
- Stage 1: Pale/blue and/or cold hand without pain
- Stage 2: Pain during exercise and/or haemodialysis
- Stage 3: Rest Pain
- Stage 4: Ulcers/necrosis/gangrene

The aim of this guideline is to develop recommendations by reviewing the available evidence on the management of steal syndrome.

**SEARCH STRATEGY**

Databases searched: MeSH terms and text words for dialysis and haemodialysis were combined with MeSH terms and text words for vascular steal syndrome. The search was carried out in Medline (1950 – August Week 1, 2011). The Cochrane Renal Trials Register was also searched for trials not indexed in Medline.

Date of search/es: August 2011.

**WHAT IS THE EVIDENCE?**

There are no randomised controlled trials relating to the diagnosis and treatment of DASS. The available evidence relating to causes, diagnosis and treatment of DASS are largely limited to case reports and retrospective reviews of case series within single centres. Furthermore, only a few studies have made comparisons between treatments and even fewer have included a control group. This limits the ability to make recommendations. In addition reported studies do not take into account the need for temporary access and associated complications. A summary of key studies contributing to the evidence is presented in Table 1.

Can DASS be predicted?

The identification of risk factors for DASS and is limited to retrospective reviews of generally small patient numbers within single centres.

The following is a summary from the available evidence:

1. Risk factors for DASS
   a. Independent risk factors for DASS include [9-13]:
      - Female gender (OR 1.77, P=0.040) [9]
      - Tobacco use (OR 2.0, P=0.048) [9]
      - Diabetes (OR 1.9, P=0.048) [9]; (OR 5, P=0.01) [10]
      - Peripheral vascular disease (OR 2.3, P=0.008) [9]
      - Coronary artery disease (OR 2.7, P<0.001) [9]
      - Hypertension (OR 2.8, P<0.001) [9]
      - Trend with increasing age [10]
   b. Inadequate arterial inflow [14].
   c. Distal arteriopathy in arteries supplying the hand [6].
   d. Upper arm AVF compared to forearm. For example in the study by Morsy et al the incidence of DASS was 4.3% in patients with upper arm AVFs compared to 1.8% in patients with forearm AVFs [15]; while Odland et al report an incidence of 1% for forearm AVFs [16]. In the review by Gupta et al [9] patients with DASS were more likely to have an upper arm fistula (OR 4.5, P<0.001).
   e. Upper arm AVF compared to grafts [13].

2. The digital brachial index (DBI) measured after the fistula has been placed has been shown to be predictive of patients who develop DASS. In a prospective study of 109 haemodialysis patients, the DBI was 0.74 +/- 0.26 (range 0.30-1.63) vs. 1.01 +/- 0.23 (range 0.45-1.76) with the AVF occluded in those who did not develop DASS. In patients who subsequently developed DASS, the DBI was 0.44 +/- 0.13 (range 0.24-0.58) (P < 0.001 versus the asymptomatic group) and 0.95 +/- 0.24 (range
0.64-1.24) with the AVF occluded (P > 0.10 versus the asymptomatic group). A DBI threshold of <0.6 predicted DASS symptoms with a sensitivity of 100%, specificity 59% and a PPV of 18% [17]. In another study of 35 patients with DBI measured pre-op, day of surgery and at 1 month, there was no decrease at one month, compared to immediately post-op. DBI in patients without steal dropped from 0.9 to 0.7. In those with symptomatic steal, DBI dropped from 0.8 – 0.4 (P < 0.01). Using DBI <0.6, sensitivity was 100% [18]. Tynan-Cuisinier et al recommend a DBI cut off of <0.45 as a more accurate predictor of significant DASS [19].

3. In a case-control study of 40 patients the change in digital pressure (CDP) with the fistula compressed was significantly greater in DASS patients compared to the controls. However, as a predictive test, CDP was less accurate than either DBI or basal digital pressure both of which were significantly lower in DASS patients compared to the controls [20].

4. Pre-operative digital pressures were examined prospectively in haemodialysis patients with brachial artery fistulas and grafts [13]. Of the 72 patients, 14 (19%) developed DASS. Those without DASS had significantly higher finger pressures of 151 +/- 27mmHg compared to those who developed DASS who had finger pressures of 131 +/- 31mmHg (P < 0.03). There was however, no absolute threshold identified below which DASS was inevitable.

5. Retrograde flow is a common phenomenon in the artery just distal to the anastomosis in 80-90% of all AV fistulas [2]. In a cross sectional study of 24 haemodialysis patients 21/24 (88%) of radio-cephalic AVF’s had diminished thumb pressures with a radio-cephalic AVF, which improved with compression of both the fistula and also the radial artery below the anastomosis. However, only one of these patients had symptoms of arterial insufficiency (i.e. DASS) [21].

In another study with mostly upper arm AVF’s or grafts showed 44% flow reversal, which again did not correlate with symptoms [22]. This study also looked at the reduction of mean peak systolic velocities in radial and ulnar arteries after arm vascular access formation, and showed no statistical correlation with change in any hand symptoms. Baseline peak systolic flow or post-op reduction in peak systolic velocity also did not correlate with development of steal symptoms in this study.

How should steal be treated?

The available evidence relating to the treatment of DASS is largely limited to case reports and case series from single centres. There are no randomised control trials and limited prospective studies. Furthermore most studies are limited to single procedures. Where multiple procedures have been reviewed, the numbers of some procedures are small thereby limiting the ability to make meaningful comparisons between treatment options. Table 1 presents a summary of studies that include assessment of outcomes associated with treatment using the following procedures [23]:

- Ligation of the AV fistula and loss of access.
- Angioplasty to treat proximal artery disease.
- Banding to increase resistance of the fistula.
- Distal revascularisation, interval ligation, where the artery distal to the fistula is ligated and a bypass graft is placed well above the fistula.
- Revision using distal inflow (RUDI), where the fistula is ligated at its origin with a bypass created from one or more distal forearm arteries.
- Proximal arterial inflow (PAI) procedure where the fistula is ligated at its origin and a PTFE graft is run from the more proximal brachial or axillary artery to the fistula.

1. Ligation of the AV fistula. This usually results in loss of symptoms, but also the loss of the access and therefore limited to severe cases of DASS [9, 11, 13, 24]. In the case of radio-cephalic end-to-side fistulas, the radial artery can be ligated below the anastomosis if there is reversed flow.

2. In the prospective case series reported by Asif et al [14], complete arteriography was performed on 12 patients with DASS symptoms. Arterial stenosis was identified in 10 patients 8 of whom were treated with angioplasty resulting in resolution of symptoms and access preservation in all 8 patients. The remaining patients were treated using surgical interventions.
3. The DRIL procedure was first described in 1988 by Schanzer [25]. This has been shown to be the best from a number of different configurations on the basis of theoretical flow modelling. An untapered 6-mm prosthetic brachial-axillary access was selected as the prototype configuration, and the theoretical effect of six access modifications on forearm flow was analysed. This showed that theoretically, DRIL was the best procedure, followed by DR without ligation, and more proximal take off procedure [26]. One group has measured pressures at various points both before and after DRIL and concluded that the improvement was due to a higher pressure at the point where the blood supply to the hand and to the fistula divide, being higher up the arm [27]. This would explain why proximalisation of the input also works.

The DRIL procedure is the most reported albeit all retrospective studies (refer to Table 1) [3, 9, 11-13, 24, 28-32]. Comparison across studies is limited due to the incomplete reporting of the severity of DASS of the included patients. The largest study by Huber at al [28] of 77 patients with moderate or severe ischaemia. Of these 61 were treated with DRIL and 16 required fistula ligation. Of the patients who underwent the DRIL procedure, the access retention rate was 100%, symptom relief 78% of patients and bypass patency rates of 77, 74 and 71% at 1, 3 and 5 years respectively. These rates are typical for all of the DRIL studies (refer to Table 1) with lower success rates being associated with more severe cases of DASS.

Where reported, patient survival following intervention is generally poor [12, 28, 30, 33] reflecting the overall poor outcomes for patients affected by DASS associated with a high prevalence of comorbidities.

4. Studies reporting results of banding to reduce the flow through the fistula are generally limited to small retrospective reviews [9, 11, 13, 15, 16, 24, 34-39]. The prime problem associated with banding is the inability to regulate access flow to improve perfusion of the hand while reducing the risk of thrombosis. As a consequence, banding is often associated with lower success rates in terms of both symptom control and maintenance of the access. A number of strategies have been used to attempt to get the balance correct:

a. Using a photoplethysmograph (PPG) on digits to assess degree of banding, however this has only been reported for 2 patients [16, 39].
b. Use of a digital pulse volume recording, however this has only been reported in a DRIL study [30].
c. Intra-operative DBI which is lower in those who develop DASS, but not different between mild/severe steal. Tynan-Cuisinier et al suggest that 50% of patients with asymptomatic DASS had an intraoperative DBI of <0.6 whereas 25% of patients with asymptomatic DASS had a DBI <0.45 [19]
d. Using clips.
e. Use of a Goretex cuff [40].
f. Using an intra-vascular balloon to tie the ligature around to get standardised size (4 or 5mm) [34, 36].

5. The RUDI procedure, which avoids ligation of the artery, has been reported in only 3 studies [9, 41, 42]. These report good success rates in terms of symptom control and maintenance of the access, however the combined studies include only 15 patients.

6. The PAI procedure, which also avoids ligation of the artery, has been reported in one study of 30 patients with severe DASS [33]. Good success rates in terms of symptom control (84% of patients) and AV access patency rates (87% at 6 months and 67% at 36 months).

7. Use of tapered grafts – 4mm versus 7mm. 4mm graft shows a 28% reduction in flow at pressure of 100mmHg [43]
SUMMARY OF THE EVIDENCE

There are no randomised controlled trials and only a small number of prospective studies examining the occurrence, diagnosis and treatment of DASS. Most studies are retrospective reviews of case series from single centres with limited controls or comparison of interventions.

Can steal be predicted?
Steal is more likely in diabetics, older patients and those with an upper arm fistula or graft, but there are no clear predictive factors.

Can steal be diagnosed?
Retrograde flow is common in patients with upper extremity AVF’s and AVF’s, however only a small proportion develop symptomatic DASS. A DBI of <0.6 after formation of a fistula is very likely to be associated with symptomatic steal.

How should steal be treated?
There are a number of options which should be tailored to the individual patient. An assessment of the arterial inflow should be performed and arterial stenosis treated. Options then include:

- Ligation of AVF
- Ligation of distal radial artery if a radio-cephalic fistula
- DRIL procedure
- PAI procedure
- RUDI procedure
- Banding of the AV fistula
- Use of a tapered graft

WHAT DO THE OTHER GUIDELINES SAY?

Kidney Disease Outcomes Quality Initiative: Guideline 16. [44]
Managing Potential Ischemia in a Limb Bearing an AV Access. All patients, particularly those in high-risk groups, should be monitored for the development of limb ischemia following AV access construction.
A. Patients in high-risk groups (diabetic, elderly, those with multiple access attempts in an extremity) should be monitored closely for the first 24 hours postoperatively. Monitoring should include: (Opinion)
1. Subjective assessment of complaints, including sensations of coldness, numbness, tingling, and impairment of motor function (not limited by postoperative pain)
2. Objective assessment of skin temperature, gross sensation, and movement and distal arterial pulses in comparison to the contralateral side
3. Teaching patients to immediately report any coldness, loss of motion, or significant reduction in sensation

B. Patients with an established fistula should be assessed monthly. The following are recommended as part of this assessment: (Opinion)
1. Obtaining an interval history of increased distal coldness or distal pain during dialysis, decreased sensation, weakness or other reduction in function, or skin changes
2. Confirming any abnormalities by physical examination.

UK Renal Association: [45]
Guideline 6.3. Treatment of ischemia related to arteriovenous fistulae or grafts. We suggest that the development of peripheral ischaemia related to arteriovenous fistulae or grafts requires early review by the vascular access surgeon to allow proactive intervention to prevent the onset of gangrene or need for amputation. (2B)

Canadian Society of Nephrology: [46]
**Guideline 3.5.1.** Monitor all patients, particularly those in high-risk groups, for the development of limb ischemia following AV access construction (opinion).

**European Best Practice Guidelines:** [47]

**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).

**International Guidelines:** No recommendation.

**SUGGESTIONS FOR FUTURE RESEARCH**

Randomised controlled trials are unlikely to take place, though it would be interesting to compare proximalisation of inflow and the DRIL procedure.

**CONFLICT OF INTEREST**

Christine Russell has no relevant financial affiliations that would cause a conflict of interest according to the conflict of interest statement set down by KHA-CARI.
REFERENCES


## APPENDICES

### Table 1. Characteristics of included studies

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| Gupta (2011)  | 114   | Retrospective review, case/control | All patients who underwent corrective procedure for DASS. Controls consecutive AV access patients from contemporary time period. | Ligation (n=27) Banding (n=22) DRIL (n=21) Improve inflow (n=9) RUDI (n=4) PAI (n=3) Revascularisation (n=1) | Not stated | ● Risk factors for DASS: Female gender (P=0.040); tobacco use (P=0.048); diabetes (P=0.016); Hypertension (P<0.001); peripheral vascular disease (P=0.008); CAD (P<0.001).
  ● Patients with DASS more likely to have upper arm fistula than those without steal (P<0.001).
  ● Success rate (resolution of DASS and preservation of AV access):
    ○ Ligation 0% (100% DASS control).
    ○ Banding 38% (19% fistula thrombosis, 48% persistence of DASS)
    ○ DRIL 80% (90% control of DASS, 10% loss of AV)
    ○ RUDI 100%
    ○ PAI 100%
    ○ Revascularisation 100%

| Callaghan (2011) | 7     | Retrospective review | All brachiocephalic or brachiobasilic AVFs with Grade 3 DASS | RUDI | Median 19 months (range 7-36) | DASS symptoms resolved in 100% of patients.
  ● 3 fistulas (43%) failed. |

| Miller (2010)   | 183   | Case series                  | Patients with DASS or high flow access. | Banding (MILLER) Mean 11 months (range, 0.25-37) |       | ● Incidence of DASS and high flow requiring treatment estimated at around 6%.
  ● Technical banding success in 98% of attempts.
  ● DASS complete symptoms relief – 89% (first banding), 96% (one or more bandings).
  ● Band related thrombectomies required in 4.4% of DASS patients.
  ● Primary access patency – 52% at 3 months in DASS patients.
  ● Secondary access patency – 90% at 24 months. |

| Huber (2008)    | 61    | Retrospective review         | All moderate or severe ischaemia (Grade 2 or 3). | DRIL | Mean 12 months (range, 0-66) | Incidence of severe hand access related ischaemia – 6%
  ● 77 patients identified of which 61 treated with DRIL and 16 with access ligation
  ● 100% access preservation.
  ● Primary DRIL patency rates
    ○ 1 year - 77±8%
    ○ 3 years - 74±9%
    ○ 5 years - 71±9%
  ● Symptom relief – 78%
  ● Patient survival
    ○ 1 year – 71±6%
    ○ 3 years – 59±7%
    ○ 5 years - 33±9% |
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| Thermann (2008)   | 63  | Retrospective    | All patients treated for DASS.                    | Conservative    |                | • Overall incidence of DASS – 5.5%  
• Conservative therapy used for 8 patients with mild symptoms.  
• Treatment success rate –  
  o Banding - 100% for patients without lesions, 94% primary patency at 1 year, early thrombosis in 1 patient.  
  o Banding - 0% for patients with lesions <1 cm and >1 cm.  
  o PAI - 94% for patients with lesions <1 cm (not used for other patient groups), 65% patency at 18 mths. |
|                    |     | review           |                                                   | Banding PAI     |                |                                                                 |
| Yu (2008)         | 24  | Retrospective    | All patients undergoing intervention for DASS     | DRIL            | Median 50      | • Incidence of significant DASS estimated at 2%.  
• Demographics  
  o Female - 58%  
  o Diabetes – 92%  
  o Hypertension – 88%  
• Patency of DRIL - 95%  
• Maintenance of access – 87%  
• Symptom control – 96%  
• Mortality – 58% |
|                    |     | review           |                                                   |                 | months         |                                                                 |
| Walz (2007)       | 33  | Retrospective    | All patients undergoing intervention for DASS     | DRIL            | Average 10.5    | • Incidence of DASS requiring DRIL – 5.4%  
• Demographics  
  o Female – 63.9%  
  o CAD – 69.4%  
  o Diabetes – 33.3%  
  o Hypertension – 88%  
  o Tobacco use – 60%  
• DRIL patency  
  o 6 months – 80%  
  o 12 months – 51%  
• Symptoms relief  
  o Relief range from 100% to 66.7% (necrosis)  
  o Complete resolution of all symptoms – 66.7%  
• Symptom development after DRIL  
  o Range from 5.6% to 0% (necrosis, gangrene)  
• Patient survival  
  o 1 year - 70%  
  o 2 years – 36% |
|                    |     | review           |                                                   |                 | months         |                                                                 |
| Mwipatayi (2006)  | 18  | Retrospective    | All patients with clinical signs of steal confirmed with PPG. | DRIL (12)       | Median 4        | • Symptom improvement with DRIL  
  o Resolved - 33.3%.  
  o Improved – 50%  
  o No improvement – 16.7%  
• All DRILL were patent at follow up.  
• All ligated patients improved.  
• Banded patient's graft thrombosed. |
<p>|                    |     | review           |                                                   | Ligation (5)    | months         |                                                                 |
|                    |     |                  |                                                   | Banding (1)     | (range 1 to 12 months) |                                                                 |
|                    |     |                  |                                                   | Angioplasty (1) |               |                                                                 |</p>
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| Goel (2006)      | 16         | Case series      | All patients with DASS requiring intervention.   | Banding (MILLER)     | Mean 3 months (maximum 11 months) | • Incidence of DASS requiring intervention estimated at 1.3%  
• Symptom improvement – 100%  
• Working access within follow up – 100%  |
| Asif (2006)      | 12         | Prospective case series | All patients with DASS symptoms.                | Angioplasty Surgical intervention | Mean 8.3 months (range, 3-18 months) | • Incidence of patients with DASS symptoms – 3.2%  
• Complete arteriography performed.  
• Arterial stenosis identified in 10 patients.  
• Angioplasty performed on 8 and surgical intervention on 4.  
• Angioplasty – 100% resolution of symptoms and 100% access preservation.  
• Surgical intervention – 100% resolution of symptoms, 1 access required ligation.                                                               |
| Zanow (2006)     | 30         | Prospective case series | All patients with severe DASS and AVF and AVG flow rates <800 ml/min and <1000 ml/min respectively. | PAI                  | Mean 26.1 months (range, 3-61 months) | • Incidence of DASS requiring intervention – 3.3%  
• PAI undertaken in 23% of patients with DASS.  
• Significant improvement in DASS symptoms - 84%  
• Primary patency rates  
  o 6 months - 87±6%  
  o 12 months – 67±11%  
• Secondary patency rates  
  o 12 months – 90±5%  
  o 24 months - 78±8%  
• Patient survival  
  o 12 months - 97±3%  
  o 36 months - 60±11%  |
| Schneider (2006) | 22 (6 with DASS) | Case series | Patients with high shunt flow treated with T-band | Banding (T-band) | 3 months | • DASS symptom relief – 5 out of 6 (83%)  
• Primary patency at 3 months – 90%  
• Secondary patency at 3 months – 100%  |
| Schanzer (2006)  | 15 (DASS) 25 (control) | Case control | Consecutive patients with symptomatic DASS. Consecutive patients without DASS. | NA                   | NA                            | • Mean BDP (30 vs 102 mmHg) and DBI (0.3 vs 0.8) significantly lower in DASS patients (P<0.001).  
• Mean CDP (85 vs 40 mmHg) was significantly higher in DASS patients (P<0.001).  
• BDP threshold 60 mmHg – sens, 100%, spec. 87%  
• DBI threshold 0.4 – sens 92%, spec.96%.  
• CDP 80 mmHg increase – sens. 78%, spec. 87%  |
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| Tynan-Cuisner     | 100| Prospective cohort | Consecutive patients receiving new AV access fistulas and grafts.            | NA        | 12 months | - DBI threshold 0.6  
  - Sensitivity – 94%  
  - Specificity - 43%  
  - PPV – 21%  
  - NPV – 98%  
- DBI threshold 0.45  
  - Sensitivity – 80%  
  - Specificity - 70%  
  - PPV – 30%  
  - NPV – 97% |
| Minion (2005)     | 4  | Case series      | Patients with DASS                                                           | RUDI      | 4 months  | - Complete symptom relief in 3 of the 4 patients.  
  - Partial symptom relief in 1 patient.  
  - No patency rates or maintenance of access reported. |
| Sessa (2004)      | 18 | Case series      | Patients with severe DASS                                                    | DRIL      | Mean 16 months (range, 5-48 months) | - Complete symptom relief – 73%.  
  - Significant improvement in symptoms – 27% |
| Davidson (2003)   | 20 | Retrospective review | All upper limb AVF and AVG patients (n=217)                                | NA        | NA        | - Overall incidence of DASS – 6.2%.  
  - Significant risk factors - univariate  
    - Diabetes  
    - AVG vs AVF  
    - Female vs male  
    - Proximal procedure  
    - CAD or CVD  
- Multivariate analysis  
  - Diabetes  
  - Aboriginal race |
| Lazarides (2003)  | 28 | Retrospective review | All patients with “limb threatening” DASS requiring surgical correction.     | DRIL      | Not stated | - Estimated incidence of “limb threatening” DASS:  
  - Overall – 4.2%  
  - AVG – 5.2%  
  - AVF – 3.4%  
- Time interval from initial access to DASS:  
  - AVG 2 days (range, 1-30)  
  - AVF 165 days (range, 60-720), P<0.001  
- Immediate, significant or complete symptom improvement – 100%  
- Thrombosis during study period – 25%  
- Symptom free cumulative patency:  
  - 1 year – 69%  
  - 2 years – 54% |
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| Papasavas        |    | Prospective cohort    | ESRD patients requiring upper extremity haemodialysis. DBI measured preoperatively, immediately after surgery and at follow-up. |                            | 1.2 months median for DBI, 12 months for DASS symptoms. | • Incidence of DASS – 6 (17%).  
• DBI values  
  o DASS – 0.8 (pre) drop to 0.4 (post)  
  o NonDASS – 0.9 (pre) drop to 0.7 (post)  
• DBI threshold <0.6 immediately post surgery (i.e. same day)  
  o Sensitivity – 100%  
  o Specificity – 76%  
  o PPV – 46% |
| (2003) [18]      | 35 |                       |                                                                              |                            |                               |                                                                                      |
| Valentine (2002) | 72 | Prospective cohort    | Haemodialysis patients with brachial artery fistulas and grafts.              | PTA                       | Not stated                     | • Incidence of DASS 19%  
• DASS developed in 50% of AVFs and 13% of AVGs (P<0.001)  
• DASS patients compared to non DASS had a higher proportion:  
  o CAD – P=0.005  
  o AVF – P=0.009 |
| [13]             |    |                       |                                                                              | DRIL Banding Ligation      |                               |                                                                                      |
| Knox (2002)      | 52 | Retrospective review  | All patients who underwent DRIL procedure.                                    | DRIL                       | Mean 16 months (range, 1-67 months) | • DASS incidence  
  o Overall - 4.6%.  
  o Female – 6.5%.  
  o Male – 2.8%.  
• DASS symptom alleviation – 90%.  
• Access ligation was required in 3 patients (6%).  
• Primary patency of DRIL  
  o 12 months - 86%  
  o 48 months - 80%  
• Patient survival  
  o 12 months - 86%  
  o 48 months - 56% |
| [12]             |    |                       |                                                                              |                            |                               |                                                                                      |
| Goldfeld (2000)  | 18 | Prospective cohort    | Patients scheduled for upper extremity proximal arteriovenous fistulas.      | NA                        | 2-4 weeks 6 months             | • Six (33%) of patients had hand symptoms within 6 weeks of surgery.  
• Reverse flow observed in 8 (44%) of patients. Only one symptomatic patient had reverse flow.  
• There was no statistical correlation between occurrence of symptoms and absolute peak systolic velocity or the magnitude of the decrease in peak systolic velocity after surgery. |
<p>| [22]             |    |                       |                                                                              |                            |                               |                                                                                      |</p>
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| Goff (2000) [17]  | 31  | Retrospective review | Patients with DASS requiring surgical intervention. Control group – random sample without DASS. Both groups had undergone postoperative DBI. Prospective study – patients undergoing AVFsurgery. | NA        | Not stated | DBI values - retrospective  
  o Control – 0.71±0.23 vs 0.91±0.21 (AVF occluded)  
  o DASS – 0.34±0.23 vs 0.78±0.21 (AVF occluded)  
 DBI values – prospective (DASS incidence n=6, 5.5%)  
  o Asymptomatic – 0.74±0.26 vs 1.01±0.23 (AVF occluded)  
  o DASS – 0.44±0.13 vs 0.95±0.24 (AVF occluded)  
 Threshold DBI value of 0.6:  
  o Sensitivity – 100%  
  o Specificity – 59%  
  o PPV – 18%  
  o NPV – 100% |
| Morsy (1998) [15] | 15  | Retrospective review | All patients diagnosed with DASS | Conservative Banding | Not stated | Incidence of DASS  
  o 4.3% AVG  
  o 1.8% AVF  
 Clinical characteristics  
  o Diabetes – 66.4%  
  o Chronic hypertension – 80%  
  o Peripheral arterial disease – 93.3%  
  o Coronary artery disease – 53.3% |
| DeCaprio (1997) [38] | 18  | Retrospective review | All patients with symptomatic DASS. | Banding (n=11) | Not stated | DASS incidence - 1.8%  
  Symptoms resolved in 10 of 11 patients.  
  Graft patency after 1 week was maintained in only 1 patient. |
| Berman (1996) [32] | 21  | Retrospective review | All patients who underwent DRIL procedure for DASS | DRIL Mean 8 months (range 1 to 31 months) |  
  o Incidence of DASS requiring DRIL – 2%  
  o Patient mortality over follow up – 29%  
  o Patency rate  
    o DRIL 18 months – 100%  
    o Access 18 months – 94%  
 Separately report on 29 patients subject to banding of which successful treatment of DASS and maintenance of the access was achieved in 15 (52%) |
| Haimov (1996) [24] | 34  | Retrospective review | Patients with severe DASS. | Banding DRIL Ligation |  
  o Banding – 4 patients  
    o 3 grafts thrombosed within 3 months  
    o 1 – open access at 1 month with partial symptom relief.  
  o Ligation – 23 patients  
    o DASS improvement after surgery – 100%  
    o Complete resolution of DASS – 83%  
    o AVF patency 73% (1 year), 45.5% (2 years)  
    o Bypass patency 95.6% (1 and 2 years) |
<table>
<thead>
<tr>
<th>Study ID</th>
<th>N</th>
<th>Study design</th>
<th>Participants</th>
<th>Procedure</th>
<th>Follow up</th>
<th>Comments and results</th>
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</table>
| Odland (1991)   | 27  | Retrospective | All patients diagnosed with DASS   | Banding   | 18 months | ● Incidence of DASS  
  ○ Overall – 5.1%.  
  ○ Radiocephalic – 1.1%  
  ○ Forearm loop arteriovenous grafts – 7.0%  
  ○ Proximal arteriovenous loop grafts – 8.6%  
  ● Fistula ligation used in 9 patients with severe DASS.  
  ● Intraoperative PPG was used to guide the degree of narrowing to achieve a digital blood pressure of 50 mm Hg.  
  ● DASS symptoms resolved in all 16 patients banded.  
  ● Graft patency  
  ○ 6 months - 62.5%  
  ○ 12 months - 38.5% |
| [16]            |     | review        |                                   |           |           |                      |
| Mattson (1987)  | 2   | Case report   | Patients with DASS                | Banding   | Not stated | ● Used PPG to guide degree of banding.  
  ● Effective symptom control and lasting access (qualitative reporting only). |
| [39]            |     |               |                                   |           |           |                      |
| Duncan (1986)   | 24  | Cross sectional | Haemodialysis patients           | NA        | NA        | ● A radial steal was indicated by an increase in the thumb/brachial ratio from 0.61 to 0.85 (P<0.001) in 21 of 24 fistulas.  
  ● Only 1 patient had DASS symptoms. |
| [21]            |     |               |                                   |           |           |                      |