Venous complications of thoracic outlet syndrome

Venous complications of thoracic outlet syndrome may be related to the position of the arm, underlying venous stenosis or repeated microtrauma of the vein. Correct management involves imaging, anticoagulation and a combination of interventional radiology techniques with or without surgery.

The term 'thoracic outlet syndrome' refers to symptoms and signs caused by compression of the neurovascular bundle exiting from the thoracic outlet into the arm. The neurogenic form is the most common with arterial and venous complications occurring in less than 10% of cases (Sanders and Pearce, 1989).

Three groups of symptomatic venous compression may be recognized. First, there may be positional compression only with symptoms arising when the arm is used in the abducted and elevated position. In the second group there is an intrinsic stenosis in the subclavian vein. The primary pathology consists of repeated microtrauma to the vein wall as a result of compression between the subclavius tendon and either the first rib or scalenus anterior muscle, or both. Repeated trauma eventually induces a fixed fibrostenosis. A third group comprises those who have progressed to thrombotic occlusion. There may be a history of repeated strenuous muscular activity in this group – the so-called Paget–Schroetter syndrome (although Paget and von Schroetter originally described primary upper limb venous thrombosis in young adults without specifically relating this to prolonged activity). The term 'effort' thrombosis is perhaps more descriptive and accurate.

The condition typically occurs in athletes such as swimmers, skiers, javelin throwers and baseball pitchers. Progression to thrombosis is accentuated by the hypercoagulability which is associated with strenuous exercise (Brandao et al, 2006). Most patients with an effort thrombosis have an underlying fibrous stricture. Schneider and colleagues (2004) reported that 64% of their patients had an intrinsic stenosis following successful thrombolysis of the clot although others have noted stenosis as a universal finding (Kreienberg et al, 2001; Molina et al, 2007). Recognition of an underlying stenosis is particularly important as this will predispose to re-thrombosis.

Within the group of patients who present with upper limb venous thrombosis are those who have no history of excessive athletic activity and no evidence of positional compression or vein wall stenosis. The term idiopathic primary thrombosis is best applied to this group although some at a later date may be shown to have an underlying unrecognized problem such as malignancy or thrombophilia.

Secondary upper limb acute venous thrombosis is much more common than primary thrombosis. It may result from a number of causes including placement of central venous catheters or pacemakers, cardiac failure, malignancy, thrombophilia, or as a complication of pregnancy or oral contraceptive medication (Hicken and Ameli, 1998). These patients are not considered further in this review.

Diagnosis

Subclavian or axillary vein thrombosis may occasionally be completely asymptomatic. Patients with either thrombosis or a severe stenosis typically exhibit swelling, cyanosis, pain and/or paraesthesiae in the limb. Apart from obvious oedema and cyanosis there may be jugular venous distension and dilated cutaneous collateral veins over the chest wall or upper arm. It may be difficult to distinguish clinically between thrombosis and a severe stenosis. Those with postural compression alone present with symptoms of venous hypertension when the arm is used in the raised or overhead position such as in swimming, driving or decorating.

Following initial presentation patients should be screened for occult malignancy, particularly gastric cancer or lymphoma (Girolami et al, 1999), and for thrombophilia especially if there is a family history of deep vein thrombosis, unexplained pregnancy loss or previous deep vein thrombosis (Cassada et al, 2006). Diagnosis can often be made by an initial duplex scan although this may sometimes give false negatives as a result of the large collaterals which may develop in some patients around the occlusive lesion. There may also be false positives because of the difficulty in imaging the proximal sub-clavian vein behind the clavicle (Baarslag et al, 2004). Those patients who have postural compression show an interruption of venous flow when the arm is abducted, extended 180° or when the shoulders are braced backwards. Venography is the gold standard and has traditionally been by intravenous

Mr Anthony S Ward *is Retired Vascular Surgeon, Basingstoke and North Hampshire Hospital, Basingstoke, Hampshire, and* **Mr Manish Chand** *is Clinical Research Fellow at The Royal Marsden Hospital, Sutton, Surrey SM2 5PT*

Correspondence to: Mr M Chand (mans001@aol.com)

injection of a superficial arm vein but computed tomography and magnetic resonance imaging venography have proved effective in identifying venous lesions. Interruption of venous flow on either duplex scanning or venography with the arm hyperabducted is not necessarily diagnostic as this sign may be seen in some asymptomatic individuals.

Upper limb venous thromboses have been thought unlikely to be complicated by pulmonary embolism when compared with lower limb thromboses. Although pulmonary embolism has been reported in up to 30% of patients with upper limb thrombosis in some series (Prandoni et al, 1997), most of these cases were of a secondary nature. Among those with primary venous thrombosis the group with effort thrombosis are least likely to be complicated by pulmonary embolism with an incidence of less than 1% (Barnett and Levitt, 1951; Adelman et al, 1997).

Therapeutic options

Positional compression

Intermittent subclavian vein obstruction without thrombosis has been recognized as a discrete entity since the 1960s (Adams et al, 1968). These patients develop venous hypertension with the arm abducted or shoulders braced and on venography or duplex scanning the vein becomes obstructed with or without venous collaterals. Medial claviculectomy has been favoured by some for this condition (Green et al, 2000) but there may be cosmetic and functional impairment with this approach and the treatment of choice is first rib resection with scalenectomy. Access for rib resection may be via the transaxillary route as popularized by Roos (1980). Others have used an infraclavicular (Murphy et al, 1980) or a supraclavicular approach (Lee et al, 2000) or a combination – para-clavicular (Melby et al, 2008).

Whichever approach is used, access to the front end of the rib is of prime importance in terms of venous as opposed to neurological decompression. Furthermore it is important to excise as much as possible of the anterior segment of the rib and to carry out an additional scalenectomy. Rib resection or scalenectomy alone are likely to be insufficient (Lee et al, 2000). In the authors' experience combined first rib resection and scalenectomy has given a high level of clinical success with reversion to a normal venographic pattern providing there is no additional intrinsic stenosis. However, there are no large scale studies of this procedure.

Subclavian or axillary vein thrombosis

In many hospitals anticoagulation has been used as the principal treatment in patients presenting with primary upper limb venous thrombosis. This approach has been more popular among physicians than vascular surgeons. Heron and colleagues (1999) reported a 46% clinical success with warfarin alone. However, limited success has been seen with anticoagulant treatment alone in patients with effort thrombosis (Fassiadis et al, 2005; Urschel and Patel, 2008) and thrombolysis is now regarded as the treatment of choice in this group.

Thrombolysis

Sabeti and colleagues (2003) noted an 88% successful lysis rate in patients with primary and secondary thrombosis following systemic thrombolysis compared with 40% with anticoagulation alone, although the complication rate was high. Most lytic treatments now involve an infusion of agents such as tissue plasminogen activator directly into the clot column via a percutaneous brachial puncture. Lysis can usually be achieved within 48 hours in up to 100% of patients with this technique (Kreienberg et al, 2001; Schneider et al, 2004). Use of pulse spray and/or mechanical thrombectomy may reduce lysis time to 2 or 3 hours only (Schneider et al, 2003; Shah et al, 2007).

Thrombolytic therapy may carry a small risk of complications particularly local or distant bleeding, the incidence varying between 1 and 12% (Kreienberg et al, 2001; Molina et al, 2007). As with thrombolysis elsewhere, contraindications to lytic therapy include active bleeding, recent operation, a history of haemorrhagic stroke and hypersensitivity to the thrombolytic agent. Despite initial concerns, thrombolytic therapy has not been associated with a significant increased risk of pulmonary emboli (Shah et al, 2007).

Thoracic outlet decompression

Following catheter-directed thrombolysis the question then arises as to whether anything further should be done. A key determinant is whether or not there is intrinsic vein stenosis or postural compression following clearance of the vein. The former cases are considered below. If there is no evidence of intrinsic vein stenosis a positional study should be undertaken. If venous flow is interrupted with the arm elevated immediate surgical decompression is indicated. Surgery should comprise resection of the first rib and scalenectomy via any of the routes described above.

Patients who do not have any evidence of postural compression or stenosis are a rather more difficult group. Long-term anticoagulation may be successful after initial thrombolysis. However, a number of these patients will develop recurrent thrombosis on a regimen of anticoagulation alone. In the series reported by Urschel and Patel (2008), 17 out of 42 patients maintained on anticoagulation after thrombolysis subsequently required thoracic outlet decompression for recurrent symptoms. Lee and colleagues (2000) similarly reported a 41% success rate on anticoagulation without recourse to surgery.

Angioplasty

Patients who are shown to have subclavian vein stenosis as a primary event and patients with a documented post-thrombolysis stenosis (*Figure 1*) should undergo angio-

plasty once the thoracic outlet has been decompressed. This can be undertaken intraoperatively (Schneider et al, 2004) or preferably in the immediate postoperative period. Angioplasty without prior thoracic outlet decompression, not surprisingly, has been shown to be ineffective (Machleder, 1993; Lee et al, 1998). The same applies to stent placement without prior decompressive surgery, the stents being subject to compression between the clavicle and first rib with subsequent fracture (Meier et al, 1996; Urschel and Patel, 2003).

Angioplasty of venous stenoses at other sites such as coronary artery bypass, lower limb bypass and haemodialysis vascular access has been associated with modest to poor results (Stone et al, 2000; Alexander and Katz, 2003; Chang et al, 2004) although angioplasty of primary lower limb vein stenosis seems more promising (Raju and Neglen, 2009). Where angioplasty has been used to treat a residual subclavian vein stenosis following thrombolysis and rib resection and/or scalenectomy, a patency at 1 year of 92% was reported by Schneider et al (2004). Kreienberg and colleagues (2001) achieved a successful result with angioplasty of a residual vein stenosis in nine out of 23 patients remaining patent at 4 years. Adequate length of follow up is essential after angioplasty in this situation.

Recurrent stenosis might then be managed by repeat angioplasty or possibly an endoluminal stent. There has been some concern over inserting stents at this site as they might be subject to stress from upper limb movement (Schneider et al, 2004), but Kreienberg and colleagues (2001) reported patency in nine of 14 vein stents at a mean follow up of 3.5 years. An alternative in those who develop recurrent stenosis following initial successful angioplasty and those in whom angioplasty is not feasible is an operative approach for surgical venous repair.

Venous reconstructive surgery

Patients with an underlying stenosis who have had initial thrombolysis and first rib resection or scalenectomy and those with recurrent intrinsic stenoses may be considered for surgical repair of the vein segment (Molina et al, 2007). It is difficult to achieve adequate access for venous repair using the standard supraclavicular or infraclavicular route. The site of the stenosis in the extreme proximal segment of the subclavian vein makes safe proximal clamp control problematic.

The solution advocated by Molina (1998) is a transmanubrial extension of an infraclavicular incision. The manubrium has to be wired in this approach and this requires the patient to severely restrict upper limb activity for 6–8 weeks postoperatively to avoid dehiscence. In one series, patching of the stenosed vein segment has a 100% patency rate if the stenosis is short and 71% patency for those requiring graft replacement (Molina et al, 2009). Others have used a paraclavicular approach with first rib resection and scalenectomy and either vein patch angioplasty or interposition grafting (Melby et al, 2008). Venous repairs in the latter series were accompanied by an arteriovenous fistula and postoperative anticoagulation. Seven of their 32 patients required a secondary procedure in the early postoperative period with either surgical revision, thrombectomy or balloon angioplasty.

Late thrombotic occlusion

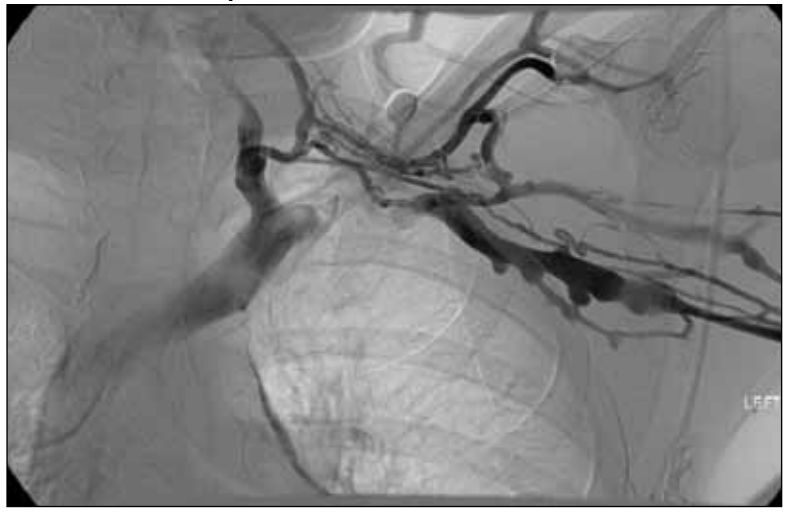
Thrombolysis has the best chance of success within the first 2 weeks of the onset of thrombosis (Hicken and Ameli, 1998; Lee et al, 2000) although Urschel and Patel (2008) have successfully treated patients up to 6 weeks post-thrombosis. However, in general the longer the delay, the less chance of success. Patients who remain significantly symptomatic with a late venous occlusion should be considered for a direct surgical approach.

Venous repair can be achieved via a combined infraclavicular and transmanubrial approach as previously described (Molina, 1998), although improved access is afforded by a full length median sternotomy with extension into the base of the neck. Reconstruction of the chronic venous occlusion can then be undertaken using a long patch or an interposition graft fashioned from the superficial femoral vein or from panels of long saphenous vein. A long saphenous vein bypass from the proximal internal jugular vein to the axillary vein using limited cervical and infraclavicular incisions is an alternative approach. Those patients not suitable for repair and who remain significantly symptomatic may be helped by compressive hosiery and/or pump therapy.

Conclusions

Venous complications of thoracic outlet syndrome may comprise positional compression, intrinsic stenosis or thrombosis. Among patients with primary upper limb venous thrombosis there is a specific subgroup of effort thrombosis. Patients with positional compression can be

Figure 1. Venogram of right arm in a young athlete following thrombolysis. An intrinsic stenosis is evident in the proximal subclavian vein.



successfully treated by first rib resection and scalenectomy. Angioplasty is the treatment of choice for patients with an intrinsic vein stenosis following rib resection and scalenectomy. Those with supervening thrombosis require initial thrombolysis followed during the same admission by first rib resection and scalenectomy with immediate postoperative angioplasty. Not all patients with a primary venous thrombosis have an underlying thoracic outlet compressive element and these patients may be managed by thrombolysis and subsequent anticoagulation. Recurrent stenoses maybe managed by angioplasty or endoluminal stent insertion. Direct venous repair with patching, interposition grafting or bypass is difficult and is required in only a very small minority of cases. Indications include stenoses resistant to angioplasty and longstanding symptomatic thrombotic occlusions. **BJHM**

The authors would like to thank Sue Hill for her help with formatting the manuscript.

Conflict of interest: none.

Adams JT, DeWeese JA, Mahoney EB, Rob CG (1968) Intermittent subclavian vein obstruction without thrombosis. *Surgery* **63:** 147–63

Adelman MA, Stone DH, Riles TS, Lamparello PJ, Giangola G, Rosen RJ (1997) A multidisciplinary approach to the treatment of Paget-Schroetter syndrome. *Ann Vasc Surg* **11:** 149–54

Alexander JQ, Katz SG (2003) The efficacy of percutaneous transluminal angioplasty in the treatment of infrainguinal vein bypass graft stenosis. *Arch Surg* **138:** 510–13

Azakie A, McElhinney DB, Thompson RW, Raven RB, Messina LM, Stoney RJ (1998) Surgical management of subclavian vein effort thrombosis as a result of thoracic outlet compression. *J Vasc Surg* **28:** 777–86

Baarslag HJ, Koopman MM, Reckers JA, Van Beek E (2004) Diagnosis and management of deep vein thrombosis of the upper extremity: a review. *Eur Radiol* **14:** 1263–74

Barnett T, Levitt LM (1951) Effort thrombosis of the axillary vein with pulmonary embolism. *JAMA* **146:** 1412–13

Brandao LR, Williams S, Kahr WH, Ryan C, Temple M, Chan AK (2006) Exercise-induced deep vein thrombosis of the upper extremity. *Acta Haematol* **115:** 214–20

Cassada DC, Lipscomb AL, Stevens SL, Freeman MB, Grandas OH, Golman MH (2006) The importance of thrombophilia in the treatment of Paget-Schroetter syndrome. *Ann Vasc Surg* **20:** 596–601

Chang C-J, Ko P-J, Hsu L-A et al (2004) Highly increased cell proliferation activity in the restenotic hemodialysis vascular access after percutaneous transluminal angioplasty: implication in prevention of restenosis. *Am J Kidney Dis* **43:** 74–84

Fassiadis N, Roidl M, South M (2005) Are we managing primary upper limb deep venous thrombosis aggressively enough in the district? *Int Angiol* **24:** 255–7

KEY POINTS

- Thoracic outlet syndrome can cause neurogenic, arterial or venous complications.
- Venous complications can arise from arm position, underlying stenosis or repeated microtrauma.
- Diagnosis is confirmed on imaging and may involve duplex ultrasound imaging, venograms and magnetic resonance imaging.
- Treatment can involve a combination of anticoagulation, interventional radiology techniques and surgery.

Girolami A, Prandoni P, Zanon E, Bagatella P, Girolami B (1999) Venous thromboses of upper limbs are more frequently associated with occult cancer as compared with those of lower limbs. *Blood Coag Fibrinol* **10:** 455–7

Green RM, Waldman D, Ouriel K, Riggs P, DeWeese JA (2000) Claviculectomy for subclavian venous repair: Long-term functional results. *J Vasc Surg* **32:** 315–21

Heron E, Lozinguez O, Emmerich J, Laurian C, Fiessinger J (1999) Long-term sequelae of spontaneous axillary-subclavian venous thrombosis. *Ann Intern Med* **131:** 510–13

Hicken JG, Ameli FM (1998) Management of subclavian-axillary vein thrombosis :a review. *Can J Surg* **41:** 13–25

Kreienberg PB, Chang BB, Darling RC et al (2001) Long-term results in patients with thrombolysis, thoracic inlet decompression and subclavian vein stenting for Paget-Schroetter syndrome. *J Vasc Surg* **33:** S100–5

Lee MC, Grassi CJ, Belkin M, Mannick JA, Whittemore AD, Donaldson MC (1998) Early operative intervention after thrombolytic therapy for primary subclavian vein thrombosis: An effective treatment approach. *J Vasc Surg* **27:** 1101–8

Lee WA, Hill BB, Harris EJ, Semba CP, Olcott C (2000) Surgical intervention is not required for all patients with subclavian vein thrombosis. *J Vasc Surg* **32:** 56–7

Machleder HI (1993) Evaluation of a new treatment strategy for Paget-Schroetter syndrome: spontaneous thrombosis of the axillary-subclavian vein. *J Vasc Surg* **17:** 305–17

Meier GH, Pollak JS, Rosenblatt M, Dickey KW, Gusberg RJ (1996) Initial experience with venous stents in exertional axillary-subclavian vein thrombosis. *J Vasc Surg* **24:** 974–83

Melby SJ, Vedantham S, Narra VR et al (2008) Comprehensive surgical management of the competitive athlete with effort thrombosis of the subclavian vein (Paget-Schroetter syndrome). *J Vasc Surg* **47:** 809–21

Molina JE (1998) A new surgical approach to the innominate and subclavian vein. *J Vasc Surg* **27:** 576–81

Molina JE, Hunter DW, Dietz CA (2007) Paget-Schroetter syndrome treated with thrombolytics and immediate surgery. *J Vasc Surg* **45:** 328–34

Molina JE, Hunter DW, Dietz CA (2009) Protocols for Paget-Schroetter syndrome and late treatment of chronic subclavian vein obstruction. *Ann Thorac Surg* **87:** 416–22

Murphy TO, Piper CA, Kanar EA, McAlexander RA (1980) Subclavicular approach to first rib resection. *Am J Surg* **139:** 634–6

Prandoni P, Polistena P, Bernadi E et al (1997) Upper extremity deep vein thrombosis. *Arch Intern Med* **157:** 57–62

Raju S, Neglen P (2009) Percutaneous recanalization of total occlusions of the iliac vein. *J Vasc Surg* **50:** 360–8

Roos DB (1980) Transaxillary first rib resection for thoracic outlet syndrome. In: Bergan JJ, Yao JS, eds. *Operative Techniques in Vascular Surgery.* Gruve and Stralton, New York: 125–30

Sabeti S, Schillinger M, Mlekusch W, Haumer M, Ahmadi R, Minar E (2003) Treatment of subclavian-axillary vein thrombosis: long term outcome of anticoagulation versus systemic thrombolysis. *Thromb Res* **108:** 279–85

Sanders RJ, Pearce WH (1989) The treatment of thoracic outlet syndrome: a comparison of different operations. *J Vasc Surg* **10:** 626–34

Schneider DB, Curry TK, Eichler CM (2003) Percutaneous mechanical thrombectomy for the management of venous thoracic outlet syndrome. *J Endovasc Ther* **10:** 336–40

Schneider DB, Dimuzio PJ, Martin N et al (2004) Combination treatment of venous thoracic outlet syndrome: open surgical decompression and intraoperative angioplasty. *J Vasc Surg* **40:** 599–603

Shah AD, Bajakian DR, Olin JW, Lookstein RA (2007) Power-pulse spray thrombectomy for treatment of Paget-Schroetter syndrome. *AJR* **188:** 1215–17

Stone GW, Brodie BR, Griffin JJ (2000) Clinical and angiographic outcomes in patients with previous coronary artery bypass graft surgery treated with primary balloon angioplasty for acute myocardial infarction. *J Am Coll Cardiol* **35:** 605–11

Urschel HC, Patel AN (2003) Paget-Schroetter syndrome therapy: failure of intravenous stents. *Ann Thorac Surg* **75:** 1693–6

Urschel HC, Patel AN (2008) Surgery remains the most effective treatment for Paget-Schroetter syndrome: 50 years' experience. *Ann Thorac Surg* **86:** 254–60