Introduction: The Amplatzer Vascular Plug (AVP) was created for peripheral embolization as a modification of the family of Amplatzer septal occluders used in the treatment of congenital heart malformations. The device has evolved over the years and multiple versions have been launched into the market. Immediate and accurate occlusion of high flow vascular malformations as well as their arterial feeders by usage sophisticated, advanced track able devices like such Avascular plug have added another tool to the armamentarium of the Interventional Radiologist. Vascular plugs are ideally suited to close extra-cardiac, high flowing vascular communications. Aims and Objectives: To study applications of vascular plugs in embolization of high flow vascular lesions. Materials and methods: Imaging proven cases of high flow vascular malformation were selected after written and informed consent. A patients were treated successfully with vascular plug after angiographic evaluation. Results: 10 embolization were performed of which 7 (70%) elective and 3 (30%) were done on emergency basis. Of these 7 cases 3 cases (42%) needed vascular plug and augmented with another embolic agents which includes coils in 1 case (16.6%) and steral in 2 cases (33.3%). Of the emergency cases 2 (66.6%) needed plug with adjunct embolic agent like gel foam in one case and coil in other. Conclusion: Successful embolization was performed in all cases. This includes pulmonary AVM, Dialysis fistula closure, Abernathy syndrome & portal hypertension. The vascular plug is a very useful embolization agent that allows the operator to treat a variety of high flow conditions including very challenging vascular lesions, such as high-flows AVF and vessels with short landing zones. There is good control on the device with minimal risk of distal embolization or migration. Becoming familiar with the different versions of the device within the AVP family and the utility of combining the AVP with other embolization therapies is very important.
The resistance to blood flow created by the nitinol mesh facilitates fibrin coverage during the clotting process. Thrombogenicity is increased by adding more braid layers or having more wire struts with smaller openings; the increased cross-sectional area coverage accelerates thrombus formation and embolization after plug placement. [6]

### AIMS AND OBJECTIVES:

To study the various uses of vascular plugs in the field of interventional radiology with its vascular and non-vascular applications

### MATERIAL AND METHODS:

Patients referred to the department of Interventional radiology with high flow vascular malformations/lesions on an emergency or elective basis were evaluated on Ultrasound, CT or DSA and were treated under fluoroscopy and ultrasound guidance with informed consent.

### OBSERVATIONS & RESULTS:

A total of 10 cases [Table 2] were referred to the Department of Vascular and Interventional Radiology in a span of 20 months which were evaluated and posted for closure using vascular plug.

Of these 2 were pediatric age group and rest were adults. One case was done on emergency basis and rest 9 were elective. Selected follow up on most cases was available.

However on follow-up, most cases had significant reduction in the complaint and most of them had no repeat episodes of the complications, however due to secondary comorbidities, few patients had to go for repeat interventions.

Of the 10 cases which presented to our institution the following specialties were involved in this study, the various specialties involved as a referral basis for such cases included:

- Gastro-Med (n = 5)
- Nephrology (n = 3)
- Cardio-vascular Surgery (n = 1)
- Otorhinolaryngology (n = 1)

Of the limited cases presented to us 4 cases needed the use of vascular plug alone as the embolic agent while rest of the 6 cases needed vascular plug along with an adjunct embolic agent which were steral in 3 cases and coils in 2 case. Repeat Intervention was required in only 1 case.

### Potential Challenges of Using the AVP:

1. Device advancement:
   - Braided sheaths are more commonly used these include Flexor Check – Flo Introducers (Cook Medical) and Destination sheaths (Terumo Medical). Non braided variety have high chances of kinking and can result in complications. Newly advanced sheaths with metallic spirals such as the Super Arrow – Flex sheaths can cause increased resistant while advancing the plug and should not be used. [7]

   A braided diagnostic catheter with 0.035” or 0.038” inner lumen system should be used along with these sheaths as delivery catheters [8]

   For the larger 7- and 8-mm AVP IVs, the use of a 5F. Guiding catheter with a 0.056” inner lumen could be very helpful. The continuous injection of normal saline through the sheath or flushing port of the AVP IV can ease the advancement of the device by reducing the friction of the plug against the catheter wall. [8, 9]

2. Persistent patency:
   - Incomplete embolization could be related to a vessel that never occludes or to a vessel that was occluded initially and then later recanalizes. [9] Incomplete embolization is caused due to the presence of a side branch that originates near the proximal end of the plug [10]

3. Vessel recanalization:
   - A vessel that was initially occluded can later recanalize, it can have serious consequences. [11, 12] This can be due to supply from new collaterals due to hyper vascularity of the lesion.

4. Plug detachment:
   - The configuration of the AVP requires a relatively straight segment of target vessel with a fairly constant diameter. With angulated branching points, jamming of the screw thread has resulted in early detachment. [13]

5. Contrast injection:
   - With the AVP IV, especially with the 7 and 8 mm sizes, it is very difficult to inject contrast through the proximal hemostatic valve due to the tight seal. [13] In such cases precise positioning has to be done prior introduction of the plug in the guiding catheter.

6. Reconfiguration:
   - Reconfiguration of the AVP was reported by Sheridan et al, where the device, due to its natural tendency to achieve its nominal diameter, resulted in shorter and wider devices in follow-up imaging. [14]

7. Device migration
   - Can be caused by a) placing an undersized plug; b) Very short landing zones; c) Surgical manipulation of vessel in which plug is deployed [15]

### Clinical Applications

#### 1. Vascular Uses

**A. ARTERIAL:**

- Pulmonary Arteriovenous Malformations Embolization
- Splenic Artery Embolization
- Embolization of Bleeders / Injuries in Aorto-iliac segments
- Arteriovenous Fistulas Embolization
- Radio embolization for hepato-cellular carcinoma

**B. VENOUS AND MESENTERIC**

- Portal and Mesenteric Venous Circulation
- Gastric Varices and Vascular plug-Assisted Retrograde Trans venous Obliteration
- Embolization of Bledgers / Injuries in Aorto-iliac segments
- Gonadal Vein Embolization
- Solid-Organ Percutaneous Access Closure
- Dialysis Fistulas Complications
- Emergency Embolization and Neurovascular Applications
2. Nonvascular Uses:

**A. GENITO URINARY APPLICATIONS**

1. VASCULAR USES:

**A) ARTERIAL USES:**

i. PULMONARY ARTERIO-VENOUS MALFORMATIONS:

Advantages include:

a. No risk of distal embolization causing stroke
b. Very distal occlusion of the feeding vessels at the venous sac thus preventing any persistent perfusion of the venous sac by collaterals
c. Mean occlusion time of simple AVM’s is approx. 3 min
d. Recanalization rate is less as compared to coils [16, 17, 18, 19]

Disadvantages of other embolic agents in such cases include:

- Coils:
  a. Needs multiple soft detachable coils
  b. Lesser control over detachment
- PVA particles:
  a. Distal embolization and stroke [18, 19]

ii. SPLENIC ARTERY EMBOLIZATION:

Advantages:

a. Better placement in long landing zones
b. Less chances of distal migration or infarction [20]
c. Less radiation dose and average procedural time [20]

Disadvantages of other embolic agents:

- Coils have a risk of distal migration (30%)

iii. EMBOLIZATION OF BLEEDERS/ INJURIES IN THE AORTO-ILIAC SEGMENTS:

Advantages of vascular plugs in this segment

a. Prevention of endoleaks type 2 by occlusion of internal iliac, inferior mesenteric artery and accessory renal arteries prior EVAR. [22, 23, 24]
b. Very proximal occlusion is possible with a single device without causing ischemia [21]

iv. ARTERIO-VENOUS FISTULA EMBOLIZATION

Advantages include:

a. Less risk of distal embolization particle migration [25, 26]
b. Treatment of arterio-venous fistulas with a short neck “stuffing technique”
c. After the plug is deployed to the mid point, the sheath is advanced over the AVP, causing the proximal tip of the AVP (still in the guiding sheath) to invaginate into the device already deployed distal half before final release [27]

v. RADIOEMBOLIZATION:

a. Embolization of any potential gastro-intestinal branch (GDA) to prevent accidental migration of radioactive particles. This can be accomplished by vascular plug which is quite proximal. In such conditions the appropriate vascular plug type used is type 4, with a 4 Fr delivery catheter device. This plug is used because of its better tracking ability. [28]

B) VENOUS AND MESENTERIC USES:

i. PORTAL AND MESENTERIC VENOUS CIRCULATION:

a. Placing a vascular plug proximally with keeping a micro-catheter distally for injection of sclerosant will prevent leaking of the sclerosant to non-targeted normal branches. [30]

ii. GASTRIC VARICES AND VASCULAR PLUG ASSISTED RETROGRADE TRANS VENOUS OBLITERATION:

a. The main complication of Balloon assisted retrograde trans venous obliteration (BRTO) is non targeted embolization due to balloon deflation or migration, a vascular plug was found to be more effective in such cases. [32]

iii. PREOPERATIVE PORTAL VEIN EMBOLIZATION:

a. Less time consuming
b. Placement of plug 1 cm distal to the portal vein bifurcation with cyanoacrylate glu-embolization of the distal portal branches [33, 34]

iv. SOLID ORGAN PERCUTANEOUS ACCESS CLOSURE:

- In certain cases where there is a necessity to get a percutaneous access via a solid organ like liver, spleen or kidney which has a high vascular flow and supply, there have been few instances like where the percutaneous access had to be modified with a larger luminal diameter sheath in cases like TIPSS closure, Percutaneous Splenic approach trans venous obliteration of lienorenal collaterals, Trans hepatic thromboaspiration of Porto-venous thrombus etc. In such cases while removing the sheath to prevent the complication of access site bleeding a vascular plug can be used during removal of sheath. [35]

v. GONADAL VEIN EMBOLIZATION:

a. To prevent reflux of the sclerosant which is injected through a micro-catheter and plug is deployed proximally. [36]

vi. EMERGENCY AND NEUROVASCULAR APPLICATIONS:

a. Rapid embolization and no distal embolization with necrosis
b. Cases like accidental intracranial vessel injuries, large intracranial and extra cranial AVM can be treated with Parent vessel occlusions and occlusion of the venous pouch in AVM’s

2) NON-VASCULAR USES:

**A) GENITO-URINARY APPLICATIONS:**

a. The ureteral closure rates combining coils with gelatin sponge or tissue adhesive have been mixed, with success rates of 50 to 100%. [37, 38]

b. Modifications to the use of the AVP include adding latex layers by placing a surgical glove finger over the plug and using the plug as a scaffold for traditional coil- and tissue-adhesive application. The success rates for these combined techniques range from 80 to 100%. [37, 38]
XI) Tables and Figures:

<table>
<thead>
<tr>
<th>Version</th>
<th>Details</th>
<th>Advantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVP I</td>
<td>Single layered disc&lt;br&gt;Short landing zone with precision&lt;br&gt;4mm to 16 mm and needs 4F - 6F sheath</td>
<td>Easy placement</td>
</tr>
<tr>
<td>AVP II</td>
<td>Braided multilayer nitinol&lt;br&gt;Faster and variable landing zones&lt;br&gt;From 2mm - 22mm&lt;br&gt;Sheaths: 4F – 7F</td>
<td>Longer segment deployment&lt;br&gt;Better apposition in short landing zones</td>
</tr>
<tr>
<td>AVP III</td>
<td>Faster occlusion in challenging high flow situations&lt;br&gt;Size: 4mm – 14 mm&lt;br&gt;Sheath: 4F – 7F</td>
<td>Tortuous anatomy</td>
</tr>
<tr>
<td>AVP IV</td>
<td>Better track ability in tortuous anatomy&lt;br&gt;Size: 4 mm to 8mm</td>
<td>For 3 - 6 mm diameter vessels</td>
</tr>
</tbody>
</table>

Table 1A. Schematic representations of types of Amplatzer vascular plugs [Source: Ref. 38]

<table>
<thead>
<tr>
<th></th>
<th>AVP I</th>
<th>AVP II</th>
<th>AVP III</th>
<th>AVP IV</th>
<th>Amplatzer cardiac plug (ACP 2)</th>
<th>Cera™</th>
</tr>
</thead>
<tbody>
<tr>
<td>Structural details</td>
<td>Single lobe</td>
<td>3 lobes plug – one central and 2 peripheral&lt;br&gt;Oblong plug with extended rims</td>
<td>Two lobes (lower profile)</td>
<td>Distal lobe with proximal disc with a waist</td>
<td>Single lobe</td>
<td></td>
</tr>
<tr>
<td>Available diametric sizes (mm)</td>
<td>4–16</td>
<td>3–22&lt;br&gt;Long axis, 4–14</td>
<td>4–8</td>
<td>16–34</td>
<td>4–24</td>
<td></td>
</tr>
<tr>
<td>Length of plug (mm)</td>
<td>7–8</td>
<td>6–18&lt;br&gt;Short axis, 2–5</td>
<td>10–13.5</td>
<td>13–18</td>
<td>7–14</td>
<td></td>
</tr>
<tr>
<td>Guide catheter (Fr)</td>
<td>5–8</td>
<td>5–9&lt;br&gt;6–9</td>
<td>5F diagnostic</td>
<td>12–14</td>
<td>4–9</td>
<td></td>
</tr>
</tbody>
</table>

Table 1B. Types of Amplatzer vascular plugs
<table>
<thead>
<tr>
<th>SR no</th>
<th>Diagnosis</th>
<th>Presenting complaints</th>
<th>Need for plug insertion</th>
<th>Access taken for plug insertion</th>
<th>Type of vascular plug</th>
<th>Additional embolising agent</th>
<th>Post procedure complications if present</th>
<th>3 months Follow Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>pulmonary sequestration</td>
<td>recurrent pneumonia</td>
<td>pre-operative for lobectomy</td>
<td>arterial access</td>
<td>type 1</td>
<td>nil</td>
<td>massive bleeding in peri-operative period due to inadvertent injury to aorta</td>
<td>No further complaints of hemoptysis</td>
</tr>
<tr>
<td>2</td>
<td>left brachio-cephalic A-V fistula with cardiac failure</td>
<td>congestive cardiac failure</td>
<td>to block fistula and reduce hyperdynamic circulation</td>
<td>venous access</td>
<td>type 2</td>
<td>nil</td>
<td>improvement of CCF</td>
<td>Thrombosed fistula on USG. On 2D Echo mild improvement on Ejection fraction</td>
</tr>
<tr>
<td>3</td>
<td>A-V fistula (brachio-cephalic) with distal digital vessels ischemia</td>
<td>fingers blanching with tingling</td>
<td>to block fistula l/v/o phenoxan</td>
<td>venous access</td>
<td>type 2</td>
<td>nil</td>
<td>improvement of digital ischemia</td>
<td>Repeal of intermittent rectal bleeding. No intervention done.</td>
</tr>
<tr>
<td>4</td>
<td>Aberranttery syndrome with recurrent rectal bleed</td>
<td>rectal bleeding intermittent</td>
<td>to block the Porta-venous fistulous communication</td>
<td>venous access as well as portal access</td>
<td>type 2</td>
<td>foaming sclerosant</td>
<td>mild improvement in rectal symptoms initially but no significant improvement on later f/u</td>
<td>Thrombosed paraumbilical vein on USG. Persistent ascites. No fresh complaints</td>
</tr>
<tr>
<td>5</td>
<td>portal hypertension with recurrent GI bleeding due to varices</td>
<td>recurrent hematemesis and melena</td>
<td>to block the engorged paraumbilical vein</td>
<td>punctaneous access and a long sheath from hepatic veins through TIPSS stent for control</td>
<td>type 2</td>
<td>gel foam</td>
<td>bleeding from punctaneous paraumbilical veens due to distension</td>
<td>Crut revealed. Thrombosed aneurysm with Splenic infarcts. Persistent low Hb due to hyperplenosis. No hematemesis</td>
</tr>
<tr>
<td>6</td>
<td>parent vessel occlusion of ICA l/v/o peri-operative injury during NA removal</td>
<td>sudden hypotension</td>
<td>to prevent perivascular leak</td>
<td>arterial access</td>
<td>type 2</td>
<td>detachable coils</td>
<td>nil</td>
<td>Lost to follow up</td>
</tr>
<tr>
<td>7</td>
<td>Splenic artery pseudoaneurysm with HB drop for coiling with plug insertion</td>
<td>Persistent GI bleed with HB drop</td>
<td>Large aneurysm with tortuous artery post coiling due to persistent filling of aneurysm</td>
<td>Arterial access</td>
<td>Type 2</td>
<td>Pushable coils</td>
<td>nil</td>
<td>Crut revealed. Thrombosed aneurysm with Splenic infarcts. Persistent low Hb due to hyperplenosis. No hematemesis</td>
</tr>
<tr>
<td>8</td>
<td>Massive hematemesis due to gastro-esophageal varices in portal hypertension</td>
<td>Massive HB drop with blood aspirate in the NG tube</td>
<td>To prevent sclerocant migration in the renal vein</td>
<td>Venous access</td>
<td>Type 2</td>
<td>Gel foam</td>
<td>nil</td>
<td>Lost to follow up</td>
</tr>
<tr>
<td>9</td>
<td>Massive gastric bleeding noted during gastroscopy during endoscopy attempt made for glu injection for varices</td>
<td>HB repeatedly dropped with melena epipides</td>
<td>To prevent sclerocant migration in left gastric and non targetedembolization</td>
<td>Venous access</td>
<td>Type 2</td>
<td>Gel foam</td>
<td>nil</td>
<td>Patient lost to follow-up</td>
</tr>
<tr>
<td>10</td>
<td>Massive retroperitoneal bleed with HB drop in a case of incidental left renal hypervascular tumor with injury to left lumbar region</td>
<td>HB drop with patient unstable to be taken to operation table</td>
<td>To prevent additional bleeding and make patient vitally stable</td>
<td>Arterial access</td>
<td>Type 1</td>
<td>Coils</td>
<td>nil</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Clinical Cases presenting to the department of Radiology at LTMGH, Sion
CASE 1 [Fig 1]:
20Y/F, with C/O hemoptysis since 5-6 yrs., each episode 30-40 ml Contrast CT showed a lung opacity with arterial supply directly from the aorta S/O Pulmonary Sequestration.

Fig 1. Pulmonary sequestration (top); vascular plug deployment (bottom left); post vascular plug deployment (bottom right)

CASE 2 [Fig 2]:
A 3.5 Yr/M with complaints of intermittent rectal bleeding;
Contrast CT shows: Prominent dilated vein at the confluence of portal and splenic v; a dilated IMV (10mm) with a dilated superior rectal vein and internal iliac vein.

Fig 2. Demonstrating closure of the porto-systemic shunt by AVP and treatment of the dilated venous channels by injection of sclerosant. Post –procedure early and delayed images of the SMA were documented which revealed no-collateral filling.

CASE 3 [Fig 3]:
15Y / M with right nasal block due to JNAF was referred for pre-operative embolization however during excision developed bleeding due to inadvertent ICA injury. Parent vessel occlusion was done with vascular plug and coils.

Fig 3. Shows leak of contrast in the pituitary fossa in cerebral angiogram (left); post plug deployment in the ICA with absence of blush and collateral filling from contralateral ICA (right)

CASE 4 [Fig 4]:
20 Y/M, K/C/O CKD on thrice a week dialysis now Came with c/c of high output cardiac failure
Closure of the A-V fistula by vascular plug with dialysis through permacath

Fig 4. Closure of venous side of brachiocephalic fistula using AVP for a patient presenting with high output cardiac failure.

CASE 5 [Fig 5]:
A case of renal transplant on immunosuppression with left brachio-cephalic fistula causing significant distal arterial steal phenomenon and digital ischemia. Patient was referred for fistula closure.

Fig 5. Fistulogram showing steal with no distal flow (top left); Compression of venous segment demonstrating forward distal arterial flow (top right); Insertion of vascular plug in fistula (bottom left); Arteriogram showing good distal flow post plug deployment (bottom right)

CASE 6 [Fig 6]:
45Y/M patient with liver cirrhosis presenting with portal hypertension and large periportal and perigastric collaterals. TIPSS shunt created to reduce portal hypertension along with vascular plug insertion for the paraumbilical collateral.

Fig 6. Portogram via transjugular approach (top left); Portogram with catheter in main portal vein (top right); Catheter in paraumbilical vein (middle row left); Vascular plug in paraumbilical vein (middle row right); Portogram post plug insertion with no retrograde flow (bottom left); TIPSS stent insertion (bottom right)
CASE 7 [Fig 7]:
44 Y/F, came with complaints of persistent GI bleed with Hb drop, CT angiogram revealed a large 5 × 6 cm pseudoaneurysm arising from mid splenic artery.

Fig 7. Plug deployment in the splenic artery with complete occlusion of distal circulation and pseudoaneurysm

CASE 8 [Fig 8]:
K/C/O Renal cell carcinoma with persistent bleeding came to emergency with hemoperitoneum. Patient was vitally unstable and was not fit for surgery.

Fig 8. Vascular Tumour seen on angiogram (right). Hence plan was made to occlude the entire left renal artery by using a vascular plug. Post plug insertion angiogram showed no flow in the left renal artery (left). Patient was immediately operated and was stable post-operative.

VIII) CONCLUSION:
Amplatzer vascular plugs are versatile occlusion devices which can be used in a wide spectrum of clinical scenarios with very high technical success rate and fewer complications and procedural time. These embolic agents have higher success rates in treatment of high flow vascular malformations and lesions as compared to other embolic agents used alone and are helpful in primary as well as adjunct treatment in such cases.

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References


