Vascular Malformations: Classification, Investigation and Treatment
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Vascular malformation has received large attention in recent years due to the frequent occurrence in newborns. Therefore, the clinical features are studied, along with other pathological subtypes, to manipulate the root cause of the disease that seems ordinary but has a great impact on the body.

Introduction

Abnormalities occurring in the fluid-carrying vessels in children and adults are referred to as vascular malformations. The abnormal development of lymph vessels, blood vessels, arteries, and veins leads to disturbances of the normal function of these structures through inflammation, pain or bleeding, causing that area to appear as a congested mass, or cosmetic blemish.

If the malformation is present at birth, it is regarded as a true vascular malformation. It develops proportionally as the child grows; it does not progress rapidly during childhood or disappear. The malformation may become visible later in life as the flow of blood increases through abnormal associations between veins and arteries. Poorly developed lymphatic channels or veins can accumulate fluid and blood, which may also lead to vascular malformations. They may impair the normal functions of the neck and head, along with other areas of the body, causing cosmetic deformities.
Definition

**Vascular malformations — abnormal clusters of blood vessels**

Abnormal clusters of blood vessels, known as vascular malformations, form during fetal development. They are idiopathic and equally affect both males and females. At birth, the lesion is always present. It might not be visible until days or even years after the child is born, but it usually develops as the child grows. Occasionally, lesions grow rapidly. However, it is more typical for them to progress steadily and gradually during infancy. They only diminish when treated.

Examples

<table>
<thead>
<tr>
<th>Vascular Malformations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemangioma</td>
</tr>
<tr>
<td>Non-neoplastic vascular malformations (AVM)</td>
</tr>
<tr>
<td>Cavernoma</td>
</tr>
<tr>
<td>Malformation of the aorta: True rings, Double arch, Coarction</td>
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<tr>
<td>Port-wine stains</td>
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</table>

Classification of Vascular Malformations

Capillary malformations

A sharply defined, flat vascular blemish of the skin is termed capillary malformation and is usually known as a port-wine stain. It may appear as speckles forming little islands of color or may cover a huge surface area. These malformations are commonly observed on the head and neck but can be present on any part of the body. They are considered as idiopathic but could arise due to the abnormal development of the minute blood vessels of the skin during the embryonic phase of life.

The presence of capillary malformations is not linked to medications or drugs taken during pregnancy or the experience of environmental abnormalities during that time.
Capillary malformations are not caused by a greater number of blood vessels in the affected area. Rather, the affected blood vessels are more dilated than normal, which causes an increase in blood flow. Since the small vessels are very close to the body surface, the increased blood flow causes the skin to appear pink to purple in color.

As the child grows, the affected blood vessels persist and increase and dilate, which in turn darkens the lesion. Eventually, the clusters of minute, dilated venules give a lumpy feel to the skin. The growth rate of a lesion may vary from person to person and can continue up to the age of 60 years.

![Image: CT (without contrast) of the brain of a 20-month-old child with Sturge-Weber syndrome, demonstrating prominent subcortical white matter calcification. By Frank Gaillard, License: CC BY-SA 3.0](image)

Capillary malformations occurring on the upper eyelid and forehead can be related to lesions of the eye and brain (Sturge-Weber syndrome). Capillary malformations occurring in the skin above the spine can be linked to the Cobb syndrome, which involves the meninges of the spine. Capillary malformations within this particular area can also be linked with other spinal abnormalities, which can be diagnosed through an MRI. Capillary malformations situated in the nose, forehead, or upper lip can be linked to brain vascular abnormalities and should also be diagnosed.

**Lymphatic malformations**
These are sponge-like accumulations of clear fluid within abnormal spaces and channels. Collecting surplus fluid from the tissues and emptying it into the venous system via minute vessels is the main function of the lymphatic system. Lymphatic malformations cause a slow transfer of the excess fluid, thus, leading to dilation of the vessels and accumulation of the fluid, resulting in inflammation of the affected area. They may also cause excessive enlargement of the bones and soft tissues.

These lesions are usually seen in the axilla and the neck but can occur in any part of the body. The dilated vessels appear larger than in other body areas. Lesions can be deep or superficial, diffused or localized. They gradually increase in size but may sometimes develop rapidly. Trauma or infection can result in abrupt but transitory enlargement.

Lymphatic malformation is considered idiopathic but is assumed to occur due to abnormal lymphatic development in the fetus. It is not affected by drugs or environmental exposure during pregnancy.

Venous malformations

Abnormally dilated or developed veins, either deep or superficial, result in venous malformations. These are the most general form of asymptomatic vascular lesion. They are naturally present at birth but are rarely seen until weeks or years later, even until adulthood.

Venous malformations develop gradually and steadily into enlarged veins. However, infection, surgery, hormonal changes, or trauma linked with puberty, menopause, or pregnancy may result in rapid enlargement. Lesions can be present anywhere in the body, including the skin, brain, mucous membrane, or internal organs.

Venous malformations are also considered idiopathic, but the general opinion is that the deficiency in smooth muscle cells in the veins could be a vital factor. Exposure to drugs and environmental factors during pregnancy has no impact on the venous development of the fetus. Alterations within the genes responsible for the communication between the smooth muscle and endothelial cells have been found.

Arteriovenous malformations (AVM)
The absence of an intervening capillary bed can cause direct associations between the arteries and veins. This leads to localized or diffuse vascular lesions, resulting in an AVM. Localized lesions are likely to be seen on the neck and head, often emerging as vascular light stains at birth and usually do not expand until early childhood or adolescence.

Lesions are often seen on the abdomen, chest, or limbs, and may not be noticeable until later in childhood as they expand with time. Lesions are noticeable in the inner organs and may be localized or diffused. They may include organs such as the liver, bowels, brain, or lungs. Lesions occurring in the brain are common AVMs. They are originally silent, with symptom development depending on their rapid enlargement.

AVMs are idiopathic and are caused by the irregular formation of the usual arterial-capillary-venous associations during the early developmental stages of life.

Genetic abnormalities that are linked with AVMs are Rasa.1 and PTEN mutations. The PTEN gene is involved in typical vascular enlargement. An alteration in PTEN would cause abnormal angiogenesis, which explains the occurrence of AVMs.

Exposure to drugs and environmental factors during pregnancy is not associated with AVMs.

**Combined vascular malformations**

The presence of 2 or more types of vessel abnormalities in an individual is defined as a combined vascular malformation. Here, the 4 types of lesions (venous, capillary, arteriovenous, or lymphatic) can be combined.

Joint malformations are typically accompanied by the overdevelopment of tissues (fat, muscle, and skin) and bones. While patients may experience some additional skin abnormalities, the usual growth is underneath. The majority of combined malformations occur in the limbs, although other parts of the body can also be involved.

Combined malformations are considered idiopathic, but could be a result of the abnormal development of various blood vessels in a particular anatomical area during the early phases of life.
Clinical Features of Vascular Malformations

Vascular malformations tend to be clinically dormant until their seemingly sudden activation occurs. They are generally diagnosed at the time of the first attack or hemorrhage. People with vascular malformation have a previous history of headaches. Afterward, the headaches may resemble an archetypal migraine. If attacks have occurred, a detailed seizure history is crucial. Seizures are partial, simple, or secondarily generalized.

Investigations and Diagnosis of Vascular Malformations

Vascular malformations are probably influenced by the hormonal changes taking place during pregnancy and puberty. They can also occur as a result of the accumulation of blood or fluid in abnormally developed lymphatic channels or veins. Usually, they are present at birth and develop in relation to the affected child; they neither progress rapidly in childhood nor disappear.

Vascular malformations can become visible later in life as the blood flow increases within the abnormal associations between veins and arteries. Internal vascular malformations can be diagnosed by an MRI scan.

Treatment of Vascular Malformations

Hemangiomas are different from true malformations because most of the vascular malformations need treatment. Although each vascular malformation cannot be totally eradicated, recent treatment techniques help in improving the look of the patient and alleviating the symptoms of pain, inflammation, and bleeding. Several adults and children with vascular malformations gain a high level of performance and achievement in college, school, and different sports after treatment.

As true vascular malformations are exceptional and intricate, the best possible outcomes are achieved with diagnosis and treatment at specialized centers. Patients with vascular malformations need individualized treatment from professionals with specific training, experience, and skills, in addition to highly developed equipment and care.

Treatment selection for vascular malformations

The cerebrovascular pediatric team and the multidisciplinary team provide the most modern and highly developed treatment for various types of vascular malformations, evaluating for the right signs and symptoms, location, and demography of the patient. These treatment methods are:

Embolization

Embolization is an invasive method where ‘glues’ or particles are used to close the abnormally developed blood vessels. Although this method can seal the abnormality in few patients, there are cases where the malformation needs to be eradicated surgically. Radiological surgery is also an option, with the use of certain types of radiation. In such cases, embolization prior to each of these techniques can minimize the malformation and assist in decreasing the risk of blood loss if surgical intervention is necessary.
Laser treatment

This is mostly used for treating venous malformations that are superficial or where a deep lesion contains a superficial component. Physicians must use their extensive knowledge to select the appropriate therapy for each patient. The lasers used for this type of treatment efficiently decrease the bluish stains of the inside layer of the skin, lips, and mouth.

A cooling device is used in tandem with the laser so that the skin is safe and intact for the curing of the vascular malformation underneath. Recently, the laser approach is often performed alongside sclerotherapy, as well as surgery, for the effective treatment of composite venous malformations.

Sclerotherapy

This technique is frequently employed in treating vascular and lymphatic malformations. A solution is injected into the anomalous vessel via the skin. The solution is able to block the vessel so that blood flow is discontinued. This leads to deterioration of the vessel and rerouting of blood toward healthier vessels.

Surgery

Surgical elimination of a vascular malformation is performed in stages, although it may also be performed as a single operation. Recently, physicians have developed a treatment in which the lesion is initially cured with sclerotherapy and later, within 48 hours, the malformation is surgically eliminated.

Using sclerotherapy reduces the risk of profound blood loss during surgery and lowers the number of required surgical procedures. The benefits of this combined treatment are notable, especially with regard to the eradication of injuries that were formerly considered untreatable.

Additionally, experience shows that large malformations cured with sclerotherapy prevent bulky disfiguration marks compared to surgery alone. In addition, microcystic (small cysts) lesions often reappear after surgery, and so several procedures are typically necessary. With sclerotherapy and a method known as the gravity technique, this
treatment has been transformed.

For vascular malformations, surgery can be a choice only after embolization. With this combination, surgery is performed 48 hours after embolization. However, if the condition is widespread, it is important to operate only on enough tissue to prevent reappearance and avoid disfigurement.

Important Notes about Vascular Malformation

<table>
<thead>
<tr>
<th>Presence at birth</th>
<th>Vascular Tumors (Hemangiomas)</th>
<th>Vascular Malformations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not present at birth but appear postnatally</td>
<td>These are errors of morphogenesis and are presumed to occur during intrauterine life → Mostly present at birth</td>
<td></td>
</tr>
</tbody>
</table>

Natural history

<table>
<thead>
<tr>
<th>Phases:</th>
<th>Proportionate growth; can expand</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Proliferating: Grows rapidly during the first year</td>
<td></td>
</tr>
<tr>
<td>2. Involuting: Slow during childhood over 2–6 years</td>
<td></td>
</tr>
<tr>
<td>3. Involuting: By the age of 10 years</td>
<td></td>
</tr>
</tbody>
</table>

Cellular

<table>
<thead>
<tr>
<th>Endothelial hyperplasia</th>
<th>Normal endothelial turnover</th>
</tr>
</thead>
</table>

Skeletal changes

| Occasional mass effect on adjacent bone | Slow-flow: Distortion, hypertrophy or hyperplasia |
| Rare hypertrophy | Fast-flow: Destruction, distortion or hypertrophy |

Important Notes about Vascular Tumors

Hemangioma of Infancy (Strawberry Hemangioma)

Most common tumor of infancy with F:M ratio (3:1)

Clinical features

Description:

- Soft bright-red (more violaceous when deeper), sharply demarcated, raised lesions
- Appearing in first 2 months → rapidly expanding → then involuting by age 5–9 years

Life cycle in 3 phases:

<table>
<thead>
<tr>
<th>Proliferation stage</th>
<th>Initial appearance as an erythematous, macular patch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Involution stage</td>
<td>Changes / deepens its color and grows faster than the growth of the child</td>
</tr>
<tr>
<td></td>
<td>Mostly started by 12 months of age</td>
</tr>
<tr>
<td></td>
<td>Slow process, is completed by the age of 5–9 years</td>
</tr>
<tr>
<td>Plateau phase</td>
<td>No growth, lasts from 9–12 months of age</td>
</tr>
</tbody>
</table>

Distribution:

- Lesions are usually solitary and localized or extend over an entire region
- Head & neck 50% / trunk 25%. Face, trunk, legs, and oral mucous
membrane

Special presentations: deep hemangioma (formerly cavernous hemangioma)
- Consists of **dilated vascular spaces** with **thin-walled endothelial cells**
- Presents as **soft blue, compressible mass up to a few centimeters in size**
- Cavernous hemangiomas may appear on the **skin, viscera, deep tissues, and mucosa** → If the larynx is involved, the obstruction may result
- **Less likely to regress spontaneously than capillary hemangiomas**
- Cavernous hemangiomas of the **brain and viscera** are associated with **von Hippel-Lindau disease**

Treatment
- **No intervention** is the best: because spontaneous resolution yields the best cosmetic results
- Treatment is indicated if a hemangioma 1) ulcerate 2) obstructs vital structures 3) may become life-threatening in the near future
  - **Surgical:** 1) Continuous-wave or pulsed dye laser; 2) Cryosurgery
  - **Medical:** 1) Intralesional and systemic high-dose glucocorticoids; 2) Interferon α (IFN-α); 3) Propanolol

<table>
<thead>
<tr>
<th>Hemangioma</th>
<th>Low Flow malformations</th>
<th>High Flow malformations</th>
<th>Rare malformations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capillary (CM)</td>
<td>COMBINED arteriovenous (AVM)</td>
<td></td>
<td>Capillary-lymphatic</td>
</tr>
<tr>
<td>Lymphatic (LM)</td>
<td></td>
<td></td>
<td>Capillary venous</td>
</tr>
<tr>
<td>Venous (VM)</td>
<td></td>
<td></td>
<td>Lymphatico-venous</td>
</tr>
<tr>
<td>Arterial (AM)</td>
<td></td>
<td></td>
<td>Capillary-lymphatico-venous</td>
</tr>
</tbody>
</table>

Pyogenic Granuloma
- Very common **solitary eroded vascular nodule** that bleeds **spontaneously or after minor trauma**
- Appears as **bright red, dusky red, violaceous, or brown-black papule** with a collar of hyperplastic epidermis at the base

Arteriovenous Malformations

Non-neoplastic vascular malformations
Present at birth, do not go through a rapid proliferative phase and do not involute

- Grow with the patient
- Approximately 31% are found in the head and neck
- Are thought to result when there is an interruption at a particular stage of development of a vessel
- Type of malformation depends on the stage which is normal morphogenesis is interrupted
- Abnormal connection between arteries and veins
- Bypassing the capillary system
- Can appear in any location
- Mostly asymptomatic
- Can cause intense pain, bleeding or lead to other serious medical problems
- Dilatation with time
- Subtype cerebral AVM
Cerebral AVM

- Classification via the Spetzler-Martin grading system
- The higher the AVM score, the more difficult the treatment

<table>
<thead>
<tr>
<th>Spetzler-Martin Grading System for AVMs</th>
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<tbody>
<tr>
<td><strong>Size of AVM</strong></td>
</tr>
<tr>
<td>Small (&lt; 3 cm)</td>
</tr>
<tr>
<td>Medium (3—6 cm)</td>
</tr>
<tr>
<td>Large (&gt; 6 cm)</td>
</tr>
<tr>
<td><strong>Eloquence of adjacent brain</strong></td>
</tr>
<tr>
<td>Non-eloquent</td>
</tr>
<tr>
<td>Eloquent</td>
</tr>
<tr>
<td><strong>Pattern of venous drainage</strong></td>
</tr>
<tr>
<td>Superficial only</td>
</tr>
<tr>
<td>Deep component</td>
</tr>
</tbody>
</table>

Clinical representation
### Hemorrhage
- (most common subarachnoid and intercerebral)

### Seizures

### Mass effect (increased intracranial pressure)

### Progressive neurologic deficit

7% of patients with AVMs present with associated aneurysms.

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### Cavernomas

#### Types of cavernomas
1. Cavernomas angioma
2. Cavernomas hemangioma

#### Symptoms
- Seizures
- Progressive neurological deficit
- Hemorrhage (usually with the brain itself)

#### Diagnosis
- CT scan
- Cerebral angiography

### Cavernomas: Capillary Malformations

#### Diagnosis
- CT
- MRI
- Angiography

#### Clinical features
- Irregularly shaped, red, or violaceous, a macular capillary malformation that is present at birth and never disappears spontaneously.
- Tends to increase in size with the growth of the child → becomes raised and nodular, causing significant disfigurement.
- Distribution: Most commonly involves the face in the distribution of the trigeminal nerve, usually the superior and middle branches.
- Mucosal involvement of the conjunctiva and mouth may occur.

#### Syndromic capillary malformation

7% of patients with AVMs present with associated aneurysms.

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### Vascular Malformations: Port-Wine Stain (nevus flammeus)

#### Symptoms
- Seizures
- Progressive neurological deficit
- Hemorrhage (usually with the brain itself)

#### Diagnosis
- CT
- MRI — hemosiderin ring ('salt and pepper' appearance)
- Angiography
Sturge-Weber syndrome is the association of port-wine stain in the trigeminal distribution with:

- **Eye:** Vascular malformations in the eye and
- **Brain:** Leptomeninges and superficial calcifications of the brain

Klippel-Trénaunay-Weber syndrome: May have an associated port-wine stain overlying the deeper vascular malformation of soft tissue and bone

**Spider Angioma (Spider Nevus)**

Consists of a bright red central papule (dilated central arteriole) surrounded by a telangiectatic network of dilated capillaries. Associated with hyperestrogenic states, such as pregnancy, in patients receiving estrogen therapy, e.g., oral contraceptives, or in those with the hepatocellular disease. May regress spontaneously.

**Cherry Angiomas (Cherry Hemangiomas), Senile Hemangiomas**

Appear during the 3rd or 4th decade of life. **Do not regress spontaneously**; numbers often increase with age. Always cutaneous and not found on the mucosa or deep tissues.

**Description:** Sharply circumscribed areas of congested capillaries and post-capillary venules in the papillary dermis.

**References**

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