Introduction

Portosystemic shunts (PSS) are anomalous vascular communications between the portal venous system (splenic, gastroduodenal, phrenic, left or right gastric and cranial mesenteric or caudal veins) and a vein that drains its blood to the heart without going through the liver (portal vein, azygos vein).

The pathophysiological consequence of this vascular anomaly is that many nutrients and toxins that are normally carried to the liver by the portal vein, pass into the general circulation. Likewise, when the liver does not receive portal blood, it will be deprived of hepatotrophic factors. This means that the liver does not reach its normal size or development, so many of these patients develop hepatic atrophy. The accumulation of toxins in the blood together with the development of liver failure result in the appearance of hepatic encephalopathy as well as vomiting or diarrhoea and crystal formation and urate stones.

There are two main types of PSS; intra and extrahepatic. Extrahepatic PSS are often observed in small or miniature breeds such as Yorkshire Terriers, Chihuahuas, Miniature Schnauzer and Maltese, although we occasionally find them in large breeds. Intrahepatic PSS most commonly occur in large breeds such as Irish Wolfhounds, Labradors or Australian Shepherds.

Patients with PSS can be treated medically, although medical treatment usually results in a shorter survival time than the surgical treatment. Surgical treatment aims to completely close the anomalous vessel, restore the hepatopetal circulation to the liver its metabolic function and make symptoms to disappear.

Five surgical modalities have been described for the closure of PSS: silk thread, ameroid ring, cellophane band, hydraulic occluder and intravascular embolization techniques. In this review we will discuss the first three, since hydraulic occlusors and intravascular techniques have been described anecdotally for extrahepatic PSS.

Silk suture

The first communications on the surgical treatment of the PSS date from the 70s, in which the technique of the silk suture was used for the closure of the PSS. Using this technique, it was necessary to measure intraoperatively the portal pressure while progressively closing the PSS using a conventional surgeon's knot. The portal pressure was measured thanks to a pressure gauge in the form of a water column. Recommendations were to begin closing the PSS with a 2-0 or 0 silk thread while measuring portal pressure, blood pressure and central venous pressure. Indirect signs of portal hypertension were also checked for. The two most common ones are: the pancreas decolours to a more greyish colour, an increase in intestinal peristalsis and a sudden intestinal corrugation. For patients in whom 20 cm H2O of portal pressure was exceeded or in which the portal pressure changed by more than 10 cm of H2O, the shunt was stopped. Around 30%-40% of the PSS could, following these recommendations, be completely
closed, and 60%-70% were partially closed, although all of them to at least 50% of their original diameter. Unfortunately, between 20 and 70% of the animals in which only a partial closure was achieved, kept having associated clinical symptoms. Even some of the patients in whom protocols were strictly followed to prevent portal hypertension developed acute portal hypertension upon recovery from anaesthesia and needed emergency surgery to remove the suture.

Progressive attenuations of PSS

Since the patients in whom the PSS is completely closed are those who have a significantly better prognosis and there are 60-70% of the dogs in which the PSS can not be closed directly, two methods of attenuation or progressive decrease in diameter were developed. In addition, some authors have proposed that the completion of a progressive closure of the PSS reduces the incidence of complications such as postoperative seizures and portal hypertension syndrome. The two methods of progressive attenuation are cellophane band and ameroid ring.

Cellophane band:

The use of cellophane paper bands for the progressive closure of PSS was first described in 1990 by Harari et al., who described the progressive closure of an azygos PSS via an intercostal thoracotomy. Since then, multiple studies have demonstrated the efficacy of these cellophane paper bands for the progressive closing PSS. Typically, the cellophane paper bands cause an inflammatory reaction around the paper, which is responsible for the progressive closing of the blood vessel around which they are placed. Initially, it was recommended to close the PSS with the cellophane paper band to a diameter less than 3 mm to favour the complete closure of PSS, although other authors recommended only placing the band around the SPS without compressing it. Several studies since its first use in 1990 have yielded very satisfactory results with favourable clinical results and return to normal liver function in up to 85% of patients. However, some studies have described some populations of PSS patients treated with cellophane paper bands in which the PSS does not close more than 30 to 50% of the original diameter in up to 35% of the treated PSS. These disparate results do not find an agreed justification to date among the scientific community. One of the possible causes of such disparate results is that the cellophane paper varies from one country to another. The first authors to describe this technique and those who coined the studies with the largest number of patients were Geraldine Hunt and her team, which used a precise cellophane paper called "Cellopaper grade MS350" from Fairfield, Australia. Cellophane is a transparent paper made of cellulose, which is often used as wrapping paper. In other continents, some authors use the paper of the tobacco packages to create cellophane bands, others, the transparent paper of florists and others the transparent paper of the gifts, since there is no cellophane paper manufactured for medical use. Thus, it is difficult to guarantee that the corner stationery or florist paper is effectively cellophane paper that will create the inflammatory reaction such as to progressively close a PSS. A recent study published in 2013 by the University of Davis, California, evaluated by spectrophotometry 5 types of transparent paper that was used clinically to attenuate PSS. Of the 5 samples available, 4 were not cellophane but polyester. Various studies have suggested that the inflammatory potential of these transparent papers depends not so much on the material they are made of (polyester vs. cellulose) but on the type of chemical components used in its manufacture. Specifically, it is believed that the chemical compound that produces the inflammatory reaction common to these bands of transparent paper is diacetyl phosphate, without necessarily being cellophane paper. It is therefore possible that the different concentrations of diacetyl phosphate present in cellophane paper or in polyester paper are responsible for the different clinical responses of these cellophane bands in the progressive closure of PSS.

It is recommended that the cellophane strips be folded in three layers to form a band about 4 mm wide. For these three layers to be folded together permanently, the author likes to use 2-0 silk thread to sew the three layers together (Image 1). The author speculates that the presence of silk thread increases the inflammatory reaction around cellophane.
The long-term prognosis with this technique has only been described by a recent study in which about 92% of patients had an excellent or good prognosis, and lived long-term without recurrence of symptomatology. However, 23% of them needed a second surgery to close the PSS with symptoms and persistent blood flow.

Image 1: Cellophane band folded in three layers and sutured together with a 2-0 silk thread. At the ends of the band the silk thread is left longer to be able to pull it and thus pass it more comfortably around the blood vessel.

Ameroid ring:

The ameroid ring is a ring composed of two main parts. The outermost part is made of stainless steel and the inner part is made of a substance called ameroid. Ameroid is a substance made from dehydrated casein. There is a slit in the part of the ring through which the PSS is inserted into the lumen of the ring. Once the PSS is placed inside the ring, a cylindrical piece is placed in the slit to close the ring leaving the PSS inside. The current recommendation is that the inner diameter of the ring should be equal to that of the PSS in the area where it is placed, so that it is in contact with the ring in all its circumference but without compressing it (Image 2).

Image 2: Ameroid ring with an internal diameter similar to the shunt it surrounds.

As the ameroid substance absorbs fluids, it expands into the lumen, where the PSS is located, since it cannot be spread out due to the presence of the outer steel part of the ring. Apart from the mechanism of expansion, it has been speculated that both the inflammatory reaction around the ring and a thrombosis induced in the vessel that is inside play a very important role in the closure of PSS. Some of the studies with the largest number of patients in which the ameroid ring was used for the closure of PSS found a persistent passage of blood through the PSS in 21% of patients, although this was documented between...
6 and 10 weeks post operatively. Subsequently, Traverson et al. published in 2017 the results of a comparative study of patients with PSS operated with cellophane bands and ameroid rings. The evaluation of the persistence of blood passage through the PSS was performed about 6 months after the surgery. In this study, all dogs operated with an ameroid ring had the PSS closed, while 35% of the PSS operated with a band of cellophane paper had not been closed.

The study with the largest number of treated animals with PSS was published in 2013 and included 209 patients in whom the PSS was attenuated with an ameroid ring. 92% of treated patients lived long-term after surgery.

**Conclusions**

Of the three methods for surgical closure of the PSS, silk sutures is the method in which it is more likely that a second surgical intervention is necessary to completely close the PSS. The use of cellophane paper band and ameroid ring are two methods of progressive closure of PSS with similar results according to the literature. There is no cellophane paper manufactured by a company of medical material and generally the surgeon does not know whether the cellophane paper is actually made of this compound (processed cellulose) or whether is made of any other type of transparent gift paper, so its capacity of creating the necessary inflammatory reaction is variable. A recent study conducted in Canada showed that up to 32% of dogs treated with cellophane paper bands still had flow through the PSS about 5 months after surgery.

It is necessary to carry out prospective studies comparing different types of transparent papers (cellophane vs. polyester) and their ability to produce inflammatory reactions to identify the ideal material to attenuate PSS. Until then, the use of ameroid rings probably gives more predictable results.

**REFERENCES**


