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Experimental Lymphatico-venous Shunt in the Rat: Pressure Controls and Long-term Patency

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Summary

In a series of rats which underwent end-to-side lymphaticovenous shunts, between precaval lymphatic collector and infrarenal cava vein, pressure values in lymphatic and venous systems and long-term patency of the anastomosis have been evaluated.
Lymphatic pressure has always been higher than venous pressure, providing a good physiological basis for the functioning of the shunt.
Short-term patency (15 days) was 100 % and long-term patency (90 days) 80 % in all the controlled animals.
The results obtained in this experimental model seem to support the efficacy of this procedure also in its clinical use.

Introduction

Several recent clinical reports have confirmed the efficacy of lymphaticovenous shunts in the treatment of lymphedema of both upper and lower limbs. The goal of this procedure is to create a new drainage to lymph flow bypassing the cause that led to development of lymphedema (1, 2, 3, 4, 5). The technique consists of a direct anastomosis between lymph vessels and humeral or saphenous vein by means of microsurgical equipment and technique.

Theoretically the most reliable and clear way to evaluate the patency of the shunt would be the lymphangiography by direct injection of an oily contrast medium.

Unfortunately this is very difficult to perform in the post-operative period because of technical difficulties in the isolation and cannulation of lymph vessels caused by the formation of the scar in the zone of the previous incision, chemical irritation to lymphatic endothelium and great disconfort to the patient in repeating this procedure after the operation. Lymphoscintigraphy is less invasive and better tolerated but does not offer comparable data about the patency of the anastomosis.

At present an appraisal of the results of the operation can only be indirectly evaluated by the post-operative clinical course and limb examination and by direct volumetry (6).

Another controversial point regards the mechanism of action of the shunt: two hypotheses have been proposed: the first implies Venturi's law, while the second is based upon the different pressure gradients existing in lymphatic and venous system on which the functional patency of the shunt depends.

In fact, with the progression of lymphedema, the pressure in the lymphatic vessel rises and overcomes venous values (*Olszewski,* personal communication). The aim of this experimental study is to directly measure the pressure values in the lymphatic and venous systems of the rat and determine if they can provided a correct physiological basis for the good functioning of the anastomosis; and to demonstrate the long-term patency of the shunt by direct visualization and examination at various times after the operation.

Materials and Methods

Male Wistar rats (mean weight: 300 gm) were used. The animals were divided into five group:

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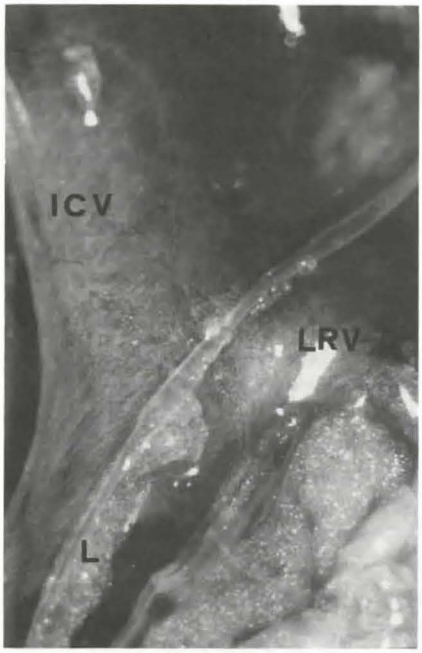

Fig. 1 The lymphatic collector and inferior vena cava are isolated (20 x). ICV: inferior cava vein; LRV: left renal vein; L: lymphatic collector

of five rats each. The first group was submitted to pressure controls only; in the other four groups a lymphatico-venous shunt was made and the patency assessed at various periods of time.

Operative technique

Under ether anesthesia, the abdominal wall of the rat is opened through a midline incision. Utilizing an operating microscope (10 to 35 magnifications), the retroperitoneum is reached and the inferior vena cava is exposed in its infrarenal tract. A lymph collector running parallel to the left side of the vena cava and draining the lymph from the hindlegs is isolated from retroperitoneal adipose tissue until it crosses the left renal vein (Fig. 1). The lymphatic is then divided and its proximal end ligated. The distal end is transfixed with a single-armed 11/0 nylon monofilament that is tied around the lymphatic wall.

The same needle is then inserted into the inferior vena cava and extracted 4–5 mm cranially. By the gentle pulling on the nylon thread, the lymphatic is cautiously brought into the vein lumen and the stich loosely tied on the outer surface of the vein wall to prevent an anastomotic stricture (Fig. 2).

Sometimes a widening of the hole in the vein wall by means of a 200 μ round needle is needed to allow the correct entrance of the lymph vessel. This technique is similar to that we use in clinical operations.

Pressure controls

Under ether anesthesia, the inferior vena cava and its proximal lymph collector are exposed in the same way as previously mentioned. The inferior vena cava is cannulated with a polyethylene tube (PE 50); the prevacal lymphatic is cannulated through a small incision on its anterior surface. A Portex tube (External diameter: 0.25 mm) is advanced downward and secured by ligation using a 10/0 nylon monofilament thread.

Pressure recordings are obtained by using a Hewlett Packard Pressure Transducer (Mod. 1280 C sensitivity = 40 μV/V/mmHg) connected to a Hewlett Packard Polygraph (Mod. 7754 A-Carrier amplifier 8805 B). The zero level was adjusted by using a Hg manometer.

Long-term patency assessment

The abdominal cavity of the operated animals is entered via a long midline incision.
The lympho-venous shunt is isolated and 0.5 cc of Patent Blue is injected into the lymphatic and its passage through the anastomosis is observed.

Results

Pressure controls

All the rats showed similar values. The free-flow pressure in the inferior vena cava varied from 0 to -2mm/Hg according to the respiratory cycle. A Valsalva manoeuver obtained by gentle compression of the rat chest wall always caused an increase in the venous pressure, which returned to normal soon after stopping the compression (Fig. 3a).

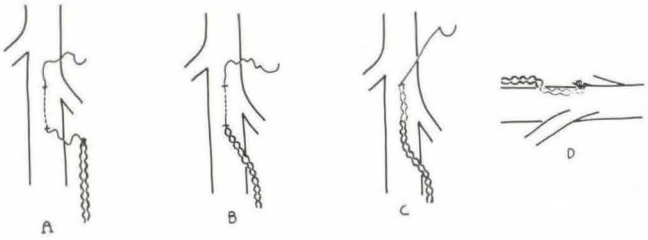

Fig. 2 Drawing of the technique used for lymphatico-venous shunt in the rat.
a) A 11/0 nylon monofilament is tied around the wall of the distal end of the lymph collector.
b) The needle is inserted in the inferior vena cava.
c) The lymph collector is cautiously brought into the vein lumen.
d) The stitch is loosely tied on the vein wall

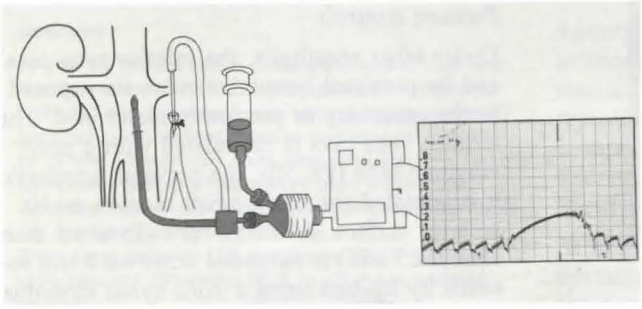

Fig. 3a Measurement of the venous pressure give always values ranging from 0 and −2 mmHg

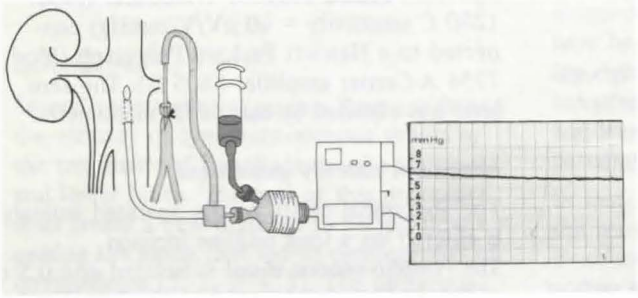

Fig. 3b The lymphatic pressure is always higher than venous ranging between 6 and 7 mmHg

The end pressure recorded in the lymphatic collector varied between +6 and +7 mmHg in all controlled animals (Fig. 3b).

A gentle bilateral inguinal massage always provoked an elevation in the intralymphatic pressure due to an increase in intralymphatic flow.

Patency Rate

The patency of the shunt was determined after 7, 15, 30 and 90 days from the operation. In the first two groups of rats (7 and 15 days post-op.) patency was 100%. In the other two groups at 30 and 90 days there was only one anastomosis out of five that failed to demonstrate a good patency, either by direct observation or by dye injection.
In these two cases the lymphatics at the level of shunt were sclerotic and their lumen completely obliterated.

The other eight rats showed a very good functioning anastomosis (Tab. 1).

Table 1 Short- and long-term patency of exerimental lympho-venous shunts

Animals submitted to L-V shunt	7-day patency	15-day patency	30 day patency	90-day patency
5	5/5			
5		5/5		
5			4/5	
5				4/5

Conclusions

Our experimental results confirm the feasibility of lympho-venous shunts in the treatment of lymphedema of the limbs.
Short-term observations showed a 100% patency rate and long-term patency (30–90 days) was 80%. No edema or infections were noted in the animals who demonstrated closure of the shunt.

Our pressure values are similar to other experimental data (7): the lymphatic pressure was always higher than the venous pressure (6–7 mmHg vs 0/–2 mmHg). This may help to explain the good functioning of the anastomosis.

Other mechanisms may contribute to the maintenance of the patency of the shunt: the development of fibrosis or another partial obstacle to lymph flow causes an elevation of intralymphatic pressure. Muscle contractions and respiratory cycle raise lymph pressure and impaire venous pressure at the same time (7). Moreover a low clotting power of lymph with a minimal fibrinogen level has been demonstrated (7). This can surely contribute to keep a low thrombosis rate at the level of the shunt.

The fact that an inguinal massage raises the lymphatic pressure, strongly recommend the clinical use of post-operative compression of the operated limb with the aim of a positive-pressure muff, as previously reported by us (3). Our data can help in explaining the satisfying clinical results obtained with the lympho-venous shunts in the treatment of lymphedemas. Further studies will be necessary however to confirm whether this hypothesis is correct and reliable in man, too.

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