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EVALUATION OF THE GREATER OMENTUM IN THE TREATMENT OF EXPERIMENTAL LYMPHEDEMA

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ABSTRACT

Despite advances in microsurgery, the most suitable operation for primary lymphedema remains unclear. A variety of tissue transplants and artificial substances have been used to facilitate drainage of peripheral lymph. The greater omentum, for example, has absorptive lymph draining capability, fights infection, and is expendable for the abdomen. Previous attempts to use the omentum in treatment of clinical lymphedema have, however, been disappointing. This discrepancy between theory and outcome prompted us to reevaluate the role of the omentum in the treatment of chronic lymphedema. In rabbits, mobilization of omentum was carefully examined by three separate techniques and the presence of natural lymph nodal-venous (L-V) shunts determined by an injection of Evans blue into the omentum with sampling later of plasma from the gastroepiploic venous blood. In dogs after promotion of unilateral chronic hindlimb lymphedema by soft tissue excision and sclerosis, the results of four methods of omental transplantation with or without L-V shunt for relief of lymphedema were compared. The results in rabbits suggest that although the greater omentum can be lengthened without jeopardizing its blood supply, it is inappropriate to lengthen it based on blood vascular arcades alone because the omental lymphatics do not strictly follow these arcades in the more distal portion, and with elongation, may be interrupted even though the blood supply remains intact. Moreover, because there is no natural L-V shunt within the greater omentum, the addition of a L-V shunt in dogs in addition to omental transplantation seems to increase effectiveness of the omentum for draining hindlimb lymph after its autotransplantation.

Although previous work has suggested the value of omental transplantation in the management of lymphedema, the clinical outcomes with this technique have been disappointing. To explain this discrepancy, we pursued experimental work in rabbits and dogs. In the first stage, the lymphangio-architecture of the greater omentum was examined in rabbits and an improved method of omental mobilization and elongation was established. In the second stage, chronic lymphedema in the dog limb was induced using a combination of operation and sclerosing agents. In the third stage, a free microvascular transplant of autogenous greater omentum was used to treat canine experimental lymphedema.

MATERIALS AND METHODS

Fifteen chinchila male and female rabbits (2-3.5kg) and 24 mongrel dogs of both sexes (6-15kg) were used in these studies.

Rabbits were anesthetized with intravenous 2.5% thiopentone and endotracheal regulated halothane anesthesia and laparotomy performed. Two ml of Evans blue was injected in the distal part of the greater omentum and its passage along lymphatics to the regional lymph nodes was noted. Gastroepiploic veins were aspirated and the plasma examined as to whether blue dye drained into the venous blood. The omentum was mobilized as shown in *Figs. 1a*, elongated as in *Fig. 1b and 1c.* Thereafter the rabbits were killed.

Dogs were anesthetized in a similar manner to the rabbits. Lymphedema was produced in one hindlimb by a combination of surgery and injection of sclerosing agents as described earlier (1-3). In brief, a 4cm strip of skin and subcutaneous tissue were removed from the middle of the right thigh. The popliteal lymph node was excised, and its afferent and efferent lymphatics were widely dissected, excised, and the ends ligated. The sciatic nerve was cleared of surrounding connective tissue as was the femoral neurovascular bundle. Thereafter, through a 1cm incision on the dorsum of the foot, lymphatics were identified, cannulated and into them 2ml of sclerosing agent (40% formalin and 70% ethyl alcohol in a 1:4 ratio) was injected. This experimental technique effectively destroyed lymphatic collectors in the hindlimb and mimicked lymphatic aplasia in patients.

After 5 months, when persistent lymphedema of the hindlimb had been achieved in 20 of 24 dogs, laparotomy was performed. The greater omentum was mobilized and/or elongated and transplanted into the lymphedematous hindlimb. For technical ease, the portion of omentum based on the right gastroepiploic blood vessels was uniformly chosen for transplantation and these blood vessels were anastomosed end-to-side to the femoral artery and vein appropriately. According to the technique used, the dogs were divided into four subgroups of five dogs each *(Table 1)*. We mobilized but did not elongate the omentum in ten dogs (Groups A,B). In five dogs we performed a lymph

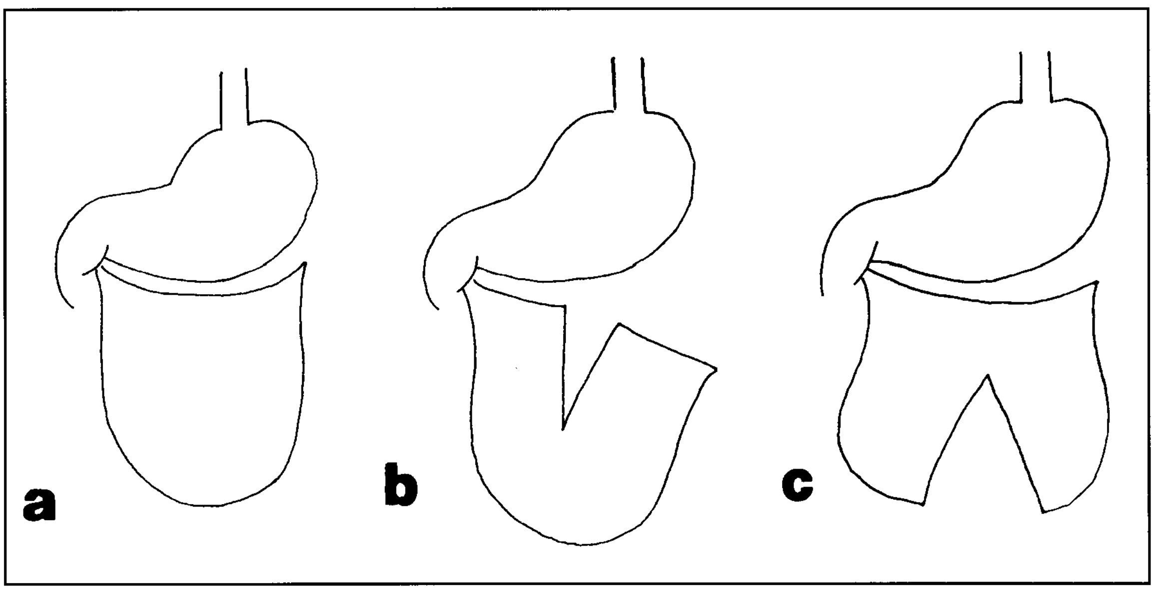

Fig. 1. Methods of mobilizing and elongating the greater omentum in rabbits. a) The greater omentum has been mobilized but not elongated (there is no interruption of either the blood or lymph systems). b) The greater omentum has been mobilized and elongated (in this method the blood supply is intact but the lymph flow is interrupted). c) The greater omentum has been mobilized and elongated (this method maintains both blood supply and lymph flow and allows a greater omental length if necessary).

TABLE 1
Four Groups of Dogs Based on the Type of Operation Used to Treat Experimental Lymphedema

Groups	Dogs (#)	Operations
A	5	Transplantation of omentum after detachment from both transverse colon and stomach *without* elongation and lymph nodal-venous anastomosis.
B	5	Transplantation of omentum after detachment from both transverse colon and stomach *without* elongation and *without* lymph nodal-venous anastomosis.
C	5	Transplantation of omentum after detachment from both transverse colon and stomach *with* elongation by incision from the *proximal side of the greater curvature of the stomach.*
D	5	Transplantation after detachment of omentum from both transverse colon and stomach with elongation from incision from the *distal side of the transverse colon.*

nodal-venous shunt (Group A) as described by Campisi (4) and Kirpatovski and Sheremet (5). In the other two groups (Groups C,D), the omentum was detached from both the transverse colon and stomach and followed by different methods of elongation to determine their bearing on lymphedema.

RESULTS

Rabbits

After injection of Evans blue, the lymph nodes along the greater curvature of the stomach were well stained and visualized by 15 minutes. They were usually ovoid in shape, about 1cm in diameter, and numbered from 1 to 4 along the right gastroepiploic vessels and 1 to 3 along the left. However, the lymph nodes of the left half drained primarily from the posterior aspect of the greater omentum whereas those nodes on the right drained mainly from the anterior aspect (6). Those nodes near the pylorus were relatively constant in location. After detachment of the greater omentum from the greater curvature of the stomach *(Fig. 1a)* or after elongation *(Fig. 1c)*, no difference occurred in the pattern of drainage of the injected blue dye. If elongation, however, was done as shown in *Fig. 1b*, the lymphatic pathways were disrupted. In other words, whereas the blood circulation was intact, the lymph circulation had been interrupted *(see Figs. 2,3)*. Absence of blue dye in the plasma of the gastroepiploic veins demonstrates a lack of natural lymphovenous shunts in the greater omentum.

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Each dog developed edema of the hindlimb after operation and sclerosis in the immediate postoperative period but it disappeared by 10-14 days. During the acute phase, the average

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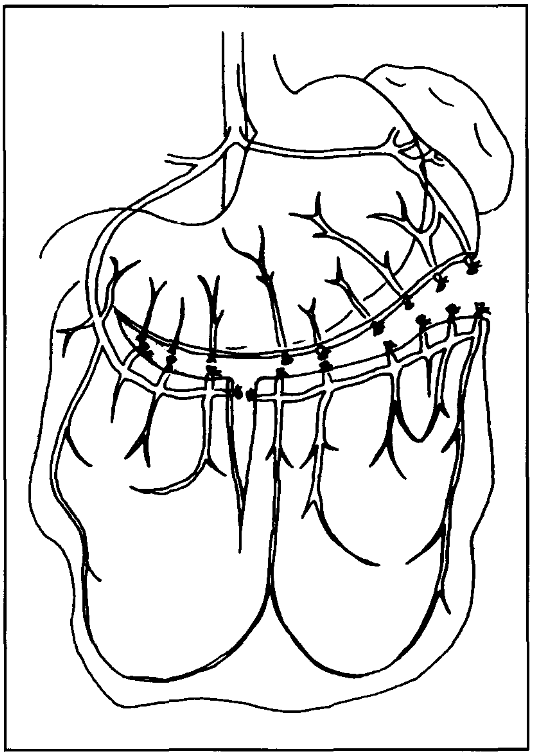

Fig. 2. *Scheme showing the blood supply of the omentum. The arcades ensure blood supply despite elongation.*

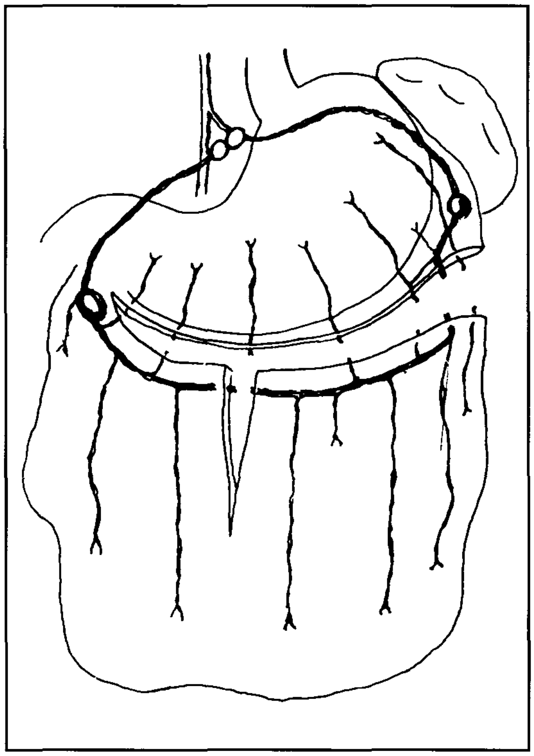

Fig. 3. *Scheme showing the lymphatics of the omentum. Note there are no intercommunications between lymphatics within the distal part of the omentum. Accordingly, if elongation is done by incision in the proximal omentum (only site of connection among lymphatics), lymph flow is interrupted despite an intact blood supply.*

difference in circumference at the knee was 5cm between the healthy and the edematous limb. After a latent period of 3-4 months, permanent but mild edema had developed in 20 of 24 dogs. Thus, the average difference in circumference at the knee between the operated and non-operated hindlimb was only 3cm. After performance of a microvascular free omental transplant as described in *Table 1*, the edematous hindlimb was evaluated two months later and that data for individual groups as well as for comparison between different groups are shown in *Tables 2-6*. Dogs with omental transplant combined with a lymph nodal-venous (L-V) shunt (Group A) had less edema than those without L-V shunt (Group B). Group C, which had elongation of the greater omentum from the proximal side of the greater curvature of the stomach, had the poorest outcome.

TABLE 2
Results of Operation for Treating Hindlimb Lymphedema in 4 Groups of Dogs as shown in Table 1

Groups	Difference in Limb Diameter* (cm)
A	0.76
B	1.19
C	2.23
D	1.18

*Compared at the knee with non-edematous contralateral hindlimb.

TABLE 3
Pre- and Post-Operative Results in Dogs of Group A with Lymphedema

	I	II	III	II-III
	16.35	19.33	17.12	2.21
	16.40	19.38	17.16	2.22
	16.20	19.25	16.95	2.30
	16.20	19.26	16.94	2.32
	16.30	19.24	17.08	2.16
Mean	16.29	10.29	17.05	2.24
SD	0.09	0.06	0.10	0.07

All measurements are in cm

I Preoperative circumference of the operated hindlimb at knee
II Circumference at knee after lymphedema had been established
III Circumference at knee after omental transplantation with L-V shunt
II-III Difference in circumference of operated limb at knee before and after omental transplantation with L-V shunt
S.D. Standard deviation

TABLE 4
Pre- and Post-Operative Results in Dogs of Group B with Lymphedema

	I	II	III	II-III
	17.20	20.18	18.35	1.83
	16.91	19.80	17.76	1.68
	16.56	19.65	17.76	1.89
	17.00	20.01	18.14	1.87
	16.83	19.85	18.03	1.82
Mean	16.90	19.90	18.01	1.82
SD	0.23	0.20	0.25	0.08

All measurements are in cm

I Preoperative circumference of the operated hindlimb at knee
II Circumference at knee after lymphedema had been established
III Circumference at knee after omental transplantation without L-V shunt
II-III Difference in circumference of operated limb at knee before and after omental transplantation with L-V shunt
S.D. Standard deviation

TABLE 5
Pre- and Post-Operative Results in Dogs of Group C with Lymphedema

	I	II	III	II-III
	16.24	19.28	18.90	0.38
	16.32	19.30	19.20	0.10
	16.65	19.57	19.06	0.51
	16.42	19.42	19.42	0.00
	16.15	19.22	18.93	0.29
Mean	16.36	19.36	19.10	0.256
SD	0.19	0.14	0.21	0.21

All measurements are in cm

I Preoperative circumference of the operated hindlimb at knee
II Circumference at knee after lymphedema had been established
III Circumference at knee after omental transplantation after elongation from the (proximal) side of greater curvature of stomach
II-III Difference in circumference of operated limb at knee before and after the above operation
S.D. Standard deviation

TABLE 6
Pre- and Post-Operative Results in Dogs of Group D with Lymphedema

	I	II	III	II-III
	17.01	19.98	18.19	1.79
	16.83	19.82	18.03	1.79
	16.45	19.50	17.64	1.86
	16.72	19.74	17.95	1.79
	16.69	19.65	17.84	1.81
Mean	16.74	19.74	17.93	1.181
SD	0.20	0.18	0.21	0.03

All measurements are in cm

I Preoperative circumference of the operated hindlimb at knee
II Circumference at knee after lymphedema had been established
III Circumference at knee after omental transplantation following elongation from the (distall) side of transverse colon
II-III Difference in circumference of operated limb at knee before and after the above operation
S.D. Standard deviation

Applying paired "t" test, the differences in circumference of operated limbs was significant ($p<0.01$) in all groups except C. And applying Fischer "t" test for comparison between individual groups (except C), results in Group A were significantly better ($p<0.01$) than in either Group B or D *(see Tables 3-6)*.

DISCUSSION

Greater omentum has long been used to cover tissue defects or improve vascularity of limbs (7,8). Goldsmith and coworkers have advocated omental transplants to treat chronic lymphedema with fair results (9,10). In experimental animals, omental transplantation has been shown by O'Brien et al (11) to be effective in treatment of canine lymphedema, but others have criticized its value because of a limited absorptive lymphatic capacity of the mammalian omentum (12). Danese et al (13) and Miller (14) observed that omentum ultimately becomes encapsulated rendering it useless as an absorptive tissue. Clodius (15) while supporting that encapsulation occurs, suggests that omentum still retains lymphatic structure and function. In none of the previous studies has emphasis been laid on the method of mobilizing the omentum and the role of lymph nodal-venous shunting. Emphasis was placed on keeping the vascularity intact while elongating the omentum to transpose it to the involved limb. As the pedicle remained within the abdomen, it was thought that a viable omentum would transport lymph from the lymphedematous limb to the omental lymph nodes by developing connections between lymphatics of omentum and those of the involved extremity. From our experimental studies in rabbits, it appears that mobilization without elongation, especially if done from proximal portion, is preferable as lymphatic collectors but not blood supply may be interrupted with elongation, especially in the proximal portion. From studies in dogs with chronic lymphedema, these technical modifications in omentum mobilization are supported and furthermore, the addition of a lymph nodal-venous shunt seems to add an alternate pathway for lymph drainage. In the absence of such a shunt, lymph drainage depends entirely on development of connections between lymphatics of the transplanted or transposed omentum and that of the lymphedematous limb. That two groups of lymph collectors can develop connections between themselves when in close proximity has previously been shown (1,13). In this study, dogs with omental transplantation without a lymph nodal-venous shunt had a beneficial effect when lymphatic collectors within the omentum were carefully preserved. This finding was presumably due to development of connections between the transplanted lymph collectors and that of the operated limb, and probably explains a beneficial effect obtained by use of omentum as used previously (9,11). Our study also demonstrates how difficult it is to mimic lymphatic aplasia in experimental animals. Despite extensive surgery and sclerosis, the lymphatics were either not totally destroyed or at least some lymphatics regenerated. Nonetheless, peripheral lymphedema characteristically developed.

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