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Integrated intestinal capacity and nutritional status following small bowel transplantation

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Abstract Successful small bowel transplantation requires normal functional capacity of the graft and unaltered metabolism of the host. Weight gain and wet weight of muscle groups and intra-abdominal fat pads were compared between transplanted, sham-operated, short bowel-operated, and normal rats that were fed either standard chow or fat-enriched (15 %) pellets. Weight gain and wet weight of muscle groups and fat pads for the control, transplanted, and sham-operated rats were identical, while short bowel animals showed reduced weight. Transplanted rats receiving fat-enriched food had lower wet weight of fat pads than control animals on the high-fat diet. We conclude that small bowel transplantation makes it possible to overcome the intestinal failure associated with short bowel syndrome, leading to overall normal weight gain and development of the recipient. However, altered fat metabolism, reflected in changed body composition, was observed in transplanted animals on the high-fat diet.

Key words Intestinal transplantation, function, rat · Small bowel function, intestinal transplantation, rat · Rat, small bowel function, intestinal transplantation

Introduction

Small bowel transplantation inevitably involves preservation injury, transection of the intestinal wall, extrinsic denervation, and interruption of the lymphatic drainage of the graft, as well as surgical trauma to the host. In addition, immune reactions (both rejection and graft-versus-host disease) as well as immunosuppressive medications are factors that can unfavorably affect the function of the transplanted small bowel and the general condition of the host. In experimental small bowel transplantation, isolated aspects of gut physiology, such as carbohydrate, water, and electrolyte absorption, have been widely investigated, whereas studies of amino acid and fat absorption per se are few [1, 9, 12–14, 21, 34]. The most important physiological aspects of small bowel transplantation are adequate integrated functional capacity of the graft and unaltered metabolism of the recipient, leading to normal weight gain and development. Cachexia associated with chronic diseases is thought to be caused by altered metabolism of the host, mediated via cytokines, and disturbed balance of insulin, glucagon, and other hormones, while in subjects suffering from intestinal failure, inadequate absorption is the main reason for wasting [5, 7, 8]. Weight gain is the variable most often used when investigating the wasting syndrome. Early in the cachetic process, muscular atrophy and reduction in size of intra-abdominal fat depots are more pronounced than loss of body weight [23, 33]. This difference in sensitivity between wet weight of fat pads and body weight as variables of altered metabolism could be enhanced by supplementation with a high-fat diet [23].

The aim of the present study was to test the hypothesis that small bowel transplantation, because of impaired graft function and altered host metabolism, could lead to wasting of the recipient. The study compared weight gain of the animal and wet weight of muscle groups and intra-abdominal fat pads in transplanted, sham-operated, short bowel, and normal rats fed either standard chow or fat-enriched pellets.

Materials and methods

Animals

Both national and European guidelines for animal experiments were adhered to. The local Ethics Committee approved the experiments.

Young, inbred Lewis rats and (Brown Norway × Lewis) F_1 hybrids of both sexes, weighing 150–250 g at the time of surgery, were used. The animals were purchased from Møllegard Breeding Center (Skensved, Denmark) and conditioned for at least 1 week before the start of the experiments. They were kept under standardized conditions and provided with water and food as described below.

Surgical procedures

The animals were anesthetized with chloral hydrate, 80 mg/ml, using 0.4 ml/100 mg body weight (b. w.), intraperitoneally (i. p.). They were kept on heating pads and rehydrated with normal saline i. p.; 2 ml of Tienam (MSD), 5 mg/ml, was given i. p. to the host animal.

In the donor animal, 45 cm of the small bowel was resected on a pedicle of the portal vein and the superior mesenteric artery (SMA). Through an indwelling catheter in the SMA, the vasculature was immediately irrigated with heparinized normal saline at room temperature, while the bowel lumen was flushed with normal saline at room temperature and 2 ml of Tienam. The graft was then stored in a plastic container surrounded by moist gauze and kept cold in an ice bath until transplanted. The donor animal was sacrificed immediately.

At the same time, the recipient animal was prepared through a midline incision. The left renal artery and vein were dissected free and clamped, followed by nephrectomy. The renal and intestinal vessels were then connected via sleeve anastomoses, a microsurgical technique described by Lauritzen [19] and modified to suit our experiments [18]. During the initial operation, a heterotopic intestinal transplantation (HIT) was performed, where the oral end of the transplanted gut was closed and the aboral end anastomosed to the native ileum, 2–3 cm from the ileocecal valve, in an end-to-side fashion. After 2 weeks, the HIT was transformed to an orthotopic transplantation (OIT). The native small bowel was resected and the oral end of the transplanted intestine was anastomosed end-to-end to the recipient jejunum, close to Treitz's ligament. The bowel anastomoses were performed by using single layer, interrupted, absorbable 6–0 sutures [4, 20, 27].

Postoperative course

During the first 24 h after surgery, the animals were kept warm and provided only with water. All animals that died within 4 days were considered technical failures (21 %).

Experimental groups

Male rats fed a normal diet (ordinary pellets) were allocated to the following groups:

1. Control (n = 8). These included normal healthy Lewis rats.
2. Sham op (n = 8). A group of sham-operated animals was created using Lewis rats. During the initial operation, left nephrectomy, ileal section, and reanastomosis were performed. After 14 days the proximal jejunum was divided and reanastomosed. No intestinal resection was performed.
3. Short bowel (n = 6). Resection of the small intestine, leaving 2.5 cm of the small bowel, was performed in order to create rats with short bowel syndrome. The animals were tube-fed 1 ml Intralipid (Kabi-Pharmacia, Uppsala, Sweden) daily for 60 days.
4. Allo CyA (n = 8). A small intestinal transplantation was performed in a semi-allogeneic (rejectional) model. The parenteral strain (Lewis rats) received a graft from an F_1 hybrid (Brown Norway × Lewis). The rats were tube-fed cyclosporin A (CyA; Sandimmun, Sandoz, Basel, Switzerland), 15 mg/kg b. w., dissolved in 1 ml Intralipid (Kabi, Pharmacia, Uppsala, Sweden) daily for 60 days.
5. Allo NIS (n = 10). Small intestinal transplantation was performed in a semi-allogeneic model as above. No treatment with cyclosporin A was given.
6. Syn (n = 10). In this group, the small bowel transplantation was done in a syngeneic fashion (Lewis-to-Lewis).

With the exception of a control n group, which was given an ordinary diet, a series of female animals were all fed fat-enriched pellets (15 % animal fat). The animals were randomized to the following groups:

1. Control n (n = 5). Normal Lewis rats were fed ordinary pellets.
2. Control f (n = 7). Normal Lewis rats were fed high-fat pellets.
3. Sham op (n = 3). Left nephrectomy, a high jejunal and a low ileal division, and reanastomoses were performed using the same procedure.
4. Short bowel (n = 4). Bowel resection was undertaken as for the male rats.
5. Syn (n = 5). Orthotopic syngeneic transplantation was performed as for rats on the normal diet.

Mortality in the transplanted animals

Of the allogeneically transplanted rats not treated with cyclosporin (Allo NIS), all rejected their grafts within 10 days postoperatively. Of the allogeneically transplanted, cyclosporin-treated animals (Allo CyA) and the syngeneically transplanted animals (Syn), one in each group suffered from necrosis of the transplanted intestine.

Weight gain and wet weight of muscle groups and fat pads

The male rats were postoperatively fed standard pellets and water ad libitum and kept in our animal quarters under daily supervision. All rats were weighed regularly for 2 months. The animals were sacrificed 2 months postoperatively. The extensor digitorum longus (EDL), soleus, and gastrocnemius muscles, as well as retroperitoneal and epidydimal fat depots, were excised bilaterally and the wet weight of the specimens was determined. Both the muscle groups and the intra-abdominal fat pads are anatomically well defined and easy to excise.

During the immediate postoperative period, the female rats were given a standard diet and water ad libitum. Two weeks after the second procedure, they were fed fat-enriched pellets (unoperated animals were of similar age). The body weight was followed regularly and after 2 months the animals were sacrificed. Wet weight of EDL, soleus, and gastrocnemius muscles, as well as retroperitoneal and parametrial fat pads, was registered.

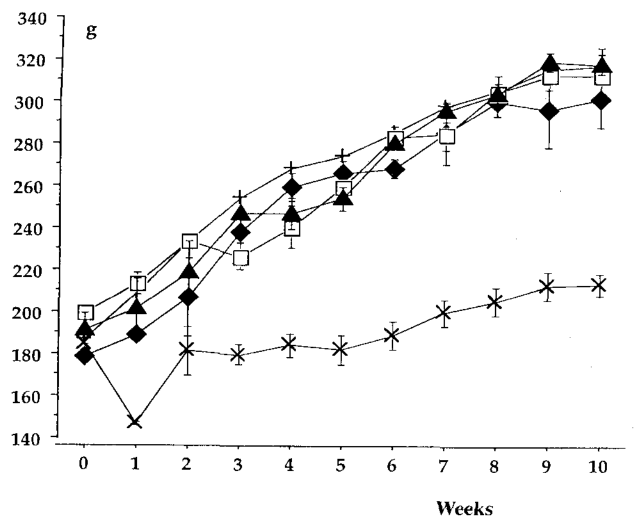

Fig. 1 Weight gain for the different groups on the normal diet. Day 0 is when the rats in the respective group were transplanted, underwent surgery, or when we started to weigh the controls. Values represent mean ± SEM. (*Controls* control rats on normal diet, *allo CyA* semi-allogeneically transplanted rats on immunosuppression with cyclosporin, *sham op* sham-operated rats, *short bowel* rats with resection of the entire small bowel, *syn* syngeneically transplanted rats) $P < 0.05$ between short bowel and each of the other groups (by ANOVA of AUC values). + Controls, ◆ allo CyA, □ sham op, × short bowel, ▲ syn

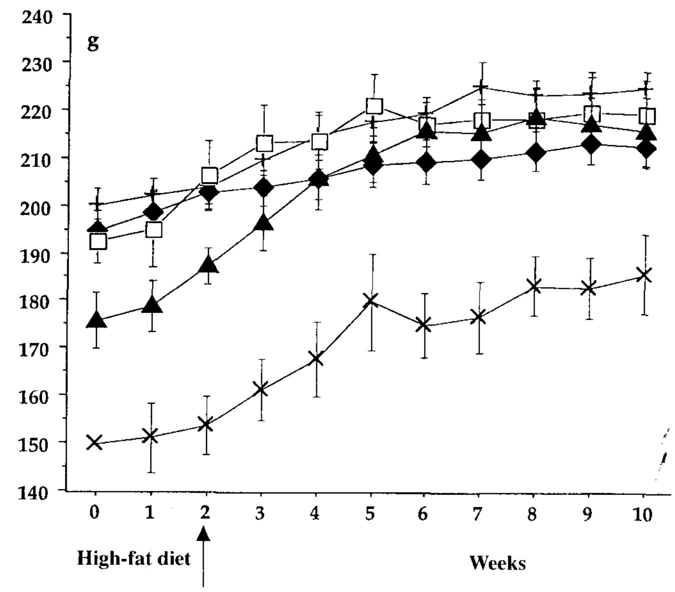

Fig. 2 Weight gain for the different groups on the high-fat diet. Day 0 is when the transplanted gut was placed in the orthotopic position, the animals underwent surgery, or when we started to weigh the controls. Values represent mean ± SEM. (*Controls f* control rats on high-fat diet, *Controls n* control rats on normal diet, *sham op* sham-operated rats, *short bowel* rats with resection of the entire small bowel, *syn* syngeneically transplanted rats) $P < 0.05$ between short bowel and each of the other groups (by ANOVA of AUC values). + Controls f, ◆ controls *n*, □ sham op, × short bowel, ▲ syn

Histology

Biopsies for histopathology were collected from the transplanted and sham-operated male animals. The specimens were immediately placed in 4 % neutral formalin. They were embedded in paraffin, sectioned at 4 mm, and stained with hematoxylin-eosin. The biopsies were classified with a semiquantitative grading system from grade zero (normal mucosa) to grade five (total destruction of the villus) and read with unknown identity. The grading system was first described by Chiu et al. [3] and later modified for use in the rat by Haglind et al. [11].

Statistical analysis

Analysis of variance (ANOVA, StatView) was applied to the integrated values (area under the curve) of weight development and to the wet weight of muscle groups and fat depots. A P value below 0.05 was considered statistically significant, if not otherwise indicated.

Results

General condition

During the 1st postoperative month especially, the short bowel animals looked generally unwell, with rugged fur, a crouching posture, and loose stools resembling steatorrhea. The other animals remained well, with no signs of diarrhea.

Weight gain

The animals in the short bowel group gained significantly less weight than those in the other groups, which showed normal weight gain (Figs. 1, 2). The difference was statistically significant. The difference in weight between the groups on the normal diet and those on the high-fat diet was due to the difference in gender.

Wet weight of muscle groups and fat pads

The animals on the normal diet showed a statistically significant difference in wet weight of fat depots and muscle mass between the short bowel group and each of the other groups comparing all of the specimens except for the soleus muscle. Only minor differences in the muscle groups were seen when comparing the controls, sham op, allo CyA, and syn animals. Syn presented with a reduction in wet weight of fat pads compared to controls, allo CyA, and sham op (Table 1), but the difference was not statistically significant.

The animals on the high-fat diet demonstrated a statistically significant reduction in wet weight of muscle groups in short bowel animals compared to the other groups. In the fat depot analysis, there was a reduction

Table 1 Wet weight of extensor digitorum longus (EDL), soleus (Sol), and gastrocnemius (Gastroc) muscles as well as epidydimal (Epid) and retroperitoneal (Retroper) fat depots bilaterally in animals on the normal diet. Mean ± SEM in grams (*Controls* unoperated rats on normal diet, *sham op* sham-operated rats, *short bowel* rats with resection of the entire small bowel, *allo CyA* semi-allogeneically transplanted rats on immunosuppression with cyclosporin, *syn* syngeneically transplanted rats)

	Unoperated	Surgically resected		Transplanted	
	Controls $n = 8$	Sham op $n = 8$	Short bowel $n = 6$	Allo CyA $n = 3$	Syn $n = 6$
EDL	0.250 ± 0.004	0.273 ± 0.007	0.181 ± 0.006*	0.244 ± 0.014	0.261 ± 0.008
Sol	0.271 ± 0.009	0.266 ± 0.015	0.219 ± 0.008*	0.249 ± 0.012**	0.267 ± 0.009
Gastroc	2.747 ± 0.035	2.896 ± 0.070	1.816 ± 0.083*	2.602 ± 0.083	2.797 ± 0.060
Epid	5.017 ± 0.180	4.475 ± 0.156	2.011 ± 0.124*	4.982 ± 0.464	4.305 ± 0.140
Retroper	6.422 ± 0.322	5.309 ± 0.435	1.624 ± 0.114*	5.899 ± 1.097	4.687 ± 0.366

* $P < 0.05$ for short bowel vs other groups; ** P = NS vs short bowel group

Table 2 Wet weight of extensor digitorum longus (EDL), soleus (Sol), and gastrocnemius (Gastroc) muscles as well as parametrial (Parametr) and retroperitoneal (Retroper) fat depots bilaterally for the different groups of animals on the high-fat diet. Mean ± SEM in grams (*Controls normal diet* control rats on normal diet, *controls high-fat diet* control rats fed high-fat diet, *sham op* sham-operated rats, *short bowel* rats with resection of the entire small bowel, *syn* syngeneically transplanted rats)

	Unoperated		Surgically resected		Transplanted
	Controls $n = 5$	Controls $n = 7$	Sham op $n = 3$	Short bowel $n = 4$	Syn $n = 4$
	Normal diet	High-fat diet			
EDL	0.191 ± 0.004	0.200 ± 0.003	0.194 ± 0.007	0.165 ± 0.010*	0.204 ± 0.012
Sol	0.211 ± 0.003	0.214 ± 0.008	0.193 ± 0.005	0.182 ± 0.014*	0.225 ± 0.013
Gastroc	1.829 ± 0.025	2.010 ± 0.052	1.902 ± 0.041	1.529 ± 0.114*	1.757 ± 0.126
Parametr	1.671 ± 0.247**	2.895 ± 0.232	3.215 ± 0.160	0.935 ± 0.250***	1.587 ± 0.040***
Retroper	1.544 ± 0.207**	2.922 ± 0.236	2.764 ± 0.474	0.846 ± 0.222***	1.567 ± 0.094***

* $P < 0.05$ vs control f, control n, syn, and sham op; ** $P < 0.05$ vs control f; *** $P < 0.05$ vs control f and sham op

in wet weight in transplanted, short bowel, and control animals on the normal diet (Table 2).

Histology

Macroscopically, the intestine of both the transplanted and sham-operated rats had a normal appearance 2 months after the initial surgery. All of the intestines showed a normal mucosa on examination by light microscopy.

Discussion

In the animals fed ordinary pellets, the surgical procedure, tentative bacterial overgrowth, and episodes of rejection did not adversely effect the functional capacity of the orthotopic small bowel transplant. The recipients were able to maintain normal nutritional status, protein and fat metabolism, body composition and development, as reflected in weight gain and wet weight determinations of muscle mass and fat depots. In contrast, short bowel-operated rats showed a different pattern, both in weight gain and wet weights of muscle mass and fat depots, illustrating that the remaining 2–3 cm of the native small intestine in the short bowel and the transplanted groups was not sufficient to maintain adequate nutritional status of the recipients. The absence of diarrhea in the transplanted groups was another factor supportive of the adequate intestinal function. Although no measurements of CyA serum concentrations were done, adequate CyA absorption was demonstrated by the survival rate in the allo CyA group. This is also an indication of normal fat absorption of the allografted small bowel, since CyA is a fat-soluble compound. The effect of CyA on fat absorption was not particularly addressed in this study, but Sigalet et al. did not find any adverse effect of CyA on nutritional status or absorption [31].

Our findings of normal intestinal function in the transplanted animals are in accordance with the results of de Bruin et al. [2], who, when studying survival rates and weight gain of small bowel transplanted rats for over a year, found no impairment in the function of the transplanted small bowel. Schraut et al. [29] and Lee et al. [22] have presented similar results. However, Koltun and Kirkman [15] found that CyA-treated allografted rats weighed significantly less than isografted controls. They considered chronic rejection as one explanation for the impaired function of the intestinal grafts seen in their study. They did not perform any histological investigation of the intestinal grafts though, while in our experiments all of the graft biopsies were normal. Kreuzer et al. [16] have reported impaired fat and protein absorption of orthotopically transplanted half-length intestines in CyA-treated allografted rats. The impaired absorption was thought to be attributed to the short intestinal graft. The immunological and metabolic effects of caval versus portal venous drainage have been reported in the literature [28, 30]. Shaffer et al. did not find any difference in nutritional status of direct venous outflow of the graft into the systemic circulation compared to portal drainage [30].

Allogeneic transplantations were not included in the experiments with animals on the high-fat diet since our primary aim was to study the effect of the transplant procedure on the metabolism of the recipient. Also, the allo CyA and syn groups on the normal diet did not present any difference in nutritional status. Although there was a difference in absolute weight due to the difference in gender, the animals on the high-fat diet were found to have a pattern of weight gain similar to the rats on the normal diet. Female rats were chosen for these experiments since the method of studying metabolism by feeding rats a high-fat diet and determining the wet weight of intra-abdominal fat pads has been described for female rats only [23]. In the wet weight of muscle groups there was a significant reduction in the short bowel group compared to all the other groups, which showed similar weight. There were no differences in wet weight of red type (Soleus) and white type (EDL) muscles, a difference seen in cancer and inflammation-associated cachexia that is considered to be induced by tumor necrosis factor [5, 7, 8]. Control animals on the normal diet had a weight development comparable to that of the animals on the high-fat diet, but the latter presented with an increased wet weight of fat pads. This finding confirms the adequacy of changed body composition, measured by wet weight of fat pads, a method applied earlier in studies of obesity and cancer cachexia, as a more sensitive means to study fat metabolism than weight gain [17, 23, 25, 33]. The altered composition of the internal fat pads in the transplanted rats could not be explained by a decreased intake of food since the animals presented with normal weight gain and wet weight of muscle groups. Impaired fat absorption has been observed earlier in small bowel transplantation [29, 32], but in our experiments it was not of a degree leading to steatorrhea. We therefore suggest that the reduced wet weight of internal fat pads was due to altered fat metabolism. Sztalryd and Kraemer [33] found a higher expression of hormone-sensitive lipase (HSL) in the white adipose tissue of gonadal and retroperitoneal fat depots than in subcutaneous fat. The lipolytic activity of HSL is regulated by catecholamines and hormones. Glucagon enhances lipolysis, while insulin has been found to mediate a decrease in HSL activity [6]. Previous studies have indicated that vagotomy may result in suppressed insulin levels, leading to higher lipolytic activity in the internal fat pads [10, 24]. Glucagon and glucagon-like peptide-1 [26], as well as other gastrointestinal hormones, could also be possible mediators of the altered fat metabolism seen in this study.

We conclude that small bowel transplantation makes it possible to overcome the wasting syndrome associated with intestinal failure in short bowel animals, resulting in overall normal weight gain and development of the recipient. Host metabolism was also found to be normal, except for fat reflected in changed body composition in transplanted animals on the high-fat diet. The importance of the latter finding needs further clarification.

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References

1. Biliar TR, Garberoglio C, Schraut WH (1984) Maltose absorption as an indicator of small intestine allograft rejection. J Surg Res 37: 75–82
2. Bruin RWF de, Heineman E, Jeekel J, Meijssen MA, Lindemans J, Bonthuis F, Marquet RL (1992) Functional aspects of small-bowel transplantation in rats. Scand J Gastroenterol 27: 483–488
3. Chiu CJ, McArdle AH, Brown R, Scott HJ, Gurd NF (1970) Intestinal mucosal lesion in low flow states. A morphologic, hemodynamic and metabolic reappraisal. Arch Surg 101: 478–483
4. Deltz E, Schroeder P, Gundlach M, Hansmann ML, Leimenstoll G (1990) Successful clinical small bowel transplantation. Transplant Proc 22: 2501
5. Espat NJ, Copeland EM, Moldawer LL (1994) Tumor necrosis factor and cachexia: a current perspective. Surg Oncol 3: 255–262
6. Ganong WF (1983) Endocrine functions of the pancreas and the regulation of carbohydrate metabolism. In: Ganong WF, Lange J, Lange D (eds) Review of medical physiology. Lange Medical Publications, Los Altos, California, pp 368–388
7. García-Martínez C, López-Soriano FJ, Argilés JM (1993) Acute treatment with tumour necrosis factor-a induces changes in protein metabolism in rat skeletal muscle. Mol Cell Biochem 125: 11–18
8. Goodman MN (1991) Tumor necrosis factor induces skeletal muscle breakdown in rats. Am J Physiol 260: E727–E730
9. Grant DR, Zhong R, Hurlbut D, Garcia B, Chen H, Lamont D, Wang P (1991) A comparison of heterotopic and orthotopic intestinal transplantation in rats. Transplantation 51: 948–954

10. Greenberg GR, Pokol DS (1994) Neural modulation of glucose-dependent insulinotropic peptide (GIP) and insulin secretion in conscious dogs. Pancreas 9: 531–535
11. Haglind E, Haglund U, Lundgren O, Romanus M, Scherstén T (1980) Graded intestinal vascular obstruction: I. Description of an experimental shock model in the rat. Circ Shock 7: 83–91
12. Hale DA, Waldorf KA, Kleinschmidt J, Pearl RH (1991) Small intestinal transplantation in non-human primates. J Pediatr Surg 26: 914–920
13. Kirkman RL, Lear PA, Madara JL, Tilney NL (1984) Small intestinal transplantation in the rat – immunology and function. Surgery 96: 280–286
14. Kirsch AJ, Kirsch SS, LaRosa CA, Jaffe BM (1991) The adaptive ability of transplanted rat small intestine. Surgery 109: 779–787
15. Koltun WA, Kirkman LR (1987) Nutritional and metabolic aspects of total small bowel transplantation in inbred rats. Transplant Proc 19: 1120–1122
16. Kreuzer M, Kirchgessner M, Ascherl R, Heinz S, Meier JHM (1990) Quantitative effects of allogeneic small-bowel transplantation on nutrient digestion and on body protein balance as determined in vivo in rats. Res Exp Med (Berl) 190: 323–335
17. Krotkiewski M, Björntorp P (1975) The effects of dexamethasone and starvation on body composition and regional adipose tissue cellularity in the rat. Acta Endocrinol (Copenh) 80: 667–675
18. Kurlberg G, Lycke N, Haglind E (1997) Migration of host and donor T cells in small bowel transplantation. Transpl Int 10: 45–50
19. Lauritzen C (1978) A new and easier way to anastomose microvessels. Scand J Plast Reconstr Surg 12: 291–294
20. Lear PA (1990) Experimental models in small-bowel transplantation. Transplant Proc 22: 2441–2442
21. Lear PA (1994) The physiology of transplanted small intestine. In: Grant D, Wood R (eds) small bowel transplantation. Edward Arnold, London Boston Melbourne Auckland, pp 18–29
22. Lee KKW, Schraut WH (1986) Structure and function of orthotopic small bowel allografts in rats treated with cyclosporine. Am J Surg 151: 55–59
23. Lemonnier D (1972) Effect of age, sex and site on the cellularity of the adipose tissue in mice and rats rendered obese by a high-fat diet. J Clin Invest 51: 2907–2915
24. Malfertheiner P, Sarr MG, Nelson DK, DiMagno EP (1994) Role of the duodenum in postprandial release of pancreatic and gastrointestinal hormones. Pancreas 9: 13–19
25. Noguchi Y, Tsuburaya A, Makino T, Fukuzawa K, Nomura K, Yoshikawa T, Matsumoto A (1993) The effects of a biological response modifier, OK-432, on tumor-induced alterations in the host metabolism. Surg Today 23: 621–625
26. Plaisancie P, Bernard C, Chayvialle JA, Cuber JC (1994) Regulation of glucagon-like peptide-1-(7–36) amide secretion by intestinal neurotransmitters and hormones in the isolated vascularly perfused rat colon. Endocrinology 135: 2398–2403
27. Schmid T, Korozsi G, Oberhuber G, Klima G, Margreiter R (1990) Lymphatic regeneration after small-bowel transplantation. Transplant Proc 22: 2446
28. Schraut WH, Lee KKW (1994) Experimental models of small bowel transplantation. In: Grant D, Wood R (eds) Small bowel transplantation. Edward Arnold, London Boston Melbourne Auckland, pp 9–17
29. Schraut WH, Lee KKW, Sitrin M (1987) Recipient growth and nutritional status following transplantation of segmental small-bowel allografts. J Surg Res 43: 1–9
30. Shaffer D, Diflo TWL, Clowes GHA, Maki T, Monaco AP (1988) Immunologic and metabolic effects of caval versus portal venous drainage in small-bowel transplantation. Surgery 104: 518–524
31. Sigalet DL, Kneteman NM, Thomson ABR (1991) The effects of cyclosporine on normal bowel. Transplantation 51: 1296–1302
32. Sigalet DL, Kneteman NM, Fedorak RN, Kizilisik AT, Thomson AB (1992) Intestinal function following allogeneic small intestinal transplantation in the rat. Transplantation 53: 264–271
33. Sztalryd C, Kraemer FB (1994) Differences in hormone-sensitive lipase expression in white adipose tissue from various anatomic locations of the rat. Metabolism 43: 241–247
34. Watson AJM, Lear PA, Montgomery A, Elliott E, Dacre J, Farthing MJ, Wood RFM (1988) Water, electrolyte, glucose and glycine absorption in rat small intestinal transplant. Gastroenterology 94: 863–869