# Effects of an Artificial Intestinal Valve on Massive Bowel Resection

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Received for Publication, Oct. 30, 1985.

## Introduction

Massive bowel resections, required in certain instances of total colon aganglionosis, intestinal atresia, necrotizing enterocolitis, or midgut volvulus during the neonatal period and in ulcerative colitis, *Crohn*'s disease, mesenteric vascular occulusions or malignancies in adults, are increasing in frequency. The operation, which entails surgical removal of more than 66% of the small bowel, results in intractable diarrhea, malabsorption, steatorrhea and precipitate weight loss. Removal of the ileocecal valve during resections of major portions of the small intestine is frequently required, however the elimination of the ileocecal valve during resection increases the severity of diarrhea and malabsorption. Actually, cases of massive intestinal resection including ileocecal valve seemed more difficult to control than cases preserving the valve.

After massive resection, functional adaptation of the residual intestine may occur, depending upon its length, location and adaptive capabilities.

Many surgical techniques have been developed to encourage residual intestine adaptation. These include vagotomy and pyloroplasty, recirculating loops, reversed segments, colonic interposition, artificial sphincters or valves, intestinal lengthening and electrical pacing. Among these, sphincter or valve formation seems to be effective in regulating transit and preventing reflux, when the ileocecal valve is removed.

Those observations accelerate development of an artificial valve compensating the loss of the ileocecal valve.

This report describes the effects of an artificial valve, formed by means of intussusception of the colon, and discusses surgical approaches to the short bowel syndrome.

## Materials and Methods

Forty-six mongrel puppies aged 3~5 months and weighing 3~6 kilograms were used in the experiment. All were dewormed and immunized for canine distemper and hepatitis at the age of 5~6 weeks. The animals were moved to the laboratory 2 to 3 weeks before the operation to

**Table 1.**  Chow Components—Oriental yeast company

| | | | | | |
|---|---|---|---|---|---|
| | water | 7.0 g | vitamin | vitamin A | 867 IU |
| | protein | 27.8 | | D$_3$ | 173 |
| | fat | 6.0 | | E | 4 mg |
| | fiber | 1.3 | | K$_3$ | 0.06 |
| | inorganic substances | 5.7 | | B$_1$ | 1.2 |
| | carbohydrates | 52.2 | | B$_2$ | 2 |
| | total energy | kcal | | B$_6$ | 1 |
| | | — | | B$_{12}$ | 5 $\mu$g |
| | energy | 374.0 | | niacin | 8 mg |
| | | — | | pantothenic Ca | 7.5 |
| amino acids | Alanine | — g | | biotin | 0.02 |
| | Arginine | 1.44 | | folic acid | 0.15 |
| | Aspartic acid | 1.46 | | inositol | 50 |
| | Cystine | 2.15 | | cholin chloride | 100 |
| | Glutamic acid | 0.30 | | vitamin C | 9.5 |
| | Glycine | 3.18 | | total | 5.7 g |
| | Histidine | 1.40 | | Ca | 0.97 |
| | Isoleucine | 0.77 | | P | 0.82 |
| | Leucine | 2.27 | | Mg | 0.19 |
| | Lysine | 1.44 | | Na | 0.40 |
| | methionyne | 0.41 | inorganic substances | K | 0.43 |
| | phenylalanine | 1.12 | | Fe | 19 mg |
| | proline | 2.01 | | Al | 5 |
| | serine | 0.70 | | Cu | 0.59 |
| | threonine | 0.68 | | Zn | 5.04 |
| | triptophane | 0.30 | | Co | 0.53 |
| | tyrosine | 0.59 | | Mn | 8.30 |
| | valine | 1.03 | | SiO$_2$ | 0.41 g |
| | | | | I | — |
| | | | | Ca/P | 1.18 |
| | | | | Ca/Mg | 5.10 |
| | | | | K/Na | 1.08 |

per 100 gm

acclimate them.

They were fed a diet of chow (Table 1) and water ad libitum.  The laboratory was kept at 24°C and 70% humidity.  During this period 14 dogs died of respiratory disease or hemorrhaging.

The remaining animals were divided into the following 5 groups : (Fig. 1)

Group A :  3 dogs, 90% resection of the distal small intestine.  The distal end of the remaining jejunum was anastomosed end-to-end to the proximal end of the remaining ileum.

Group B :  8 dogs, 80% resection of the distal small intestine.

Group C :  10 dogs, 80% resection of the distal small intestine, including the ileocecal valve.  The distal end of the remaining jejunum was anastomosed end-to-end to the ascending colon.

Group D :  3 dogs, 80% resection of the small intestine, including the ileocecal valve.  An
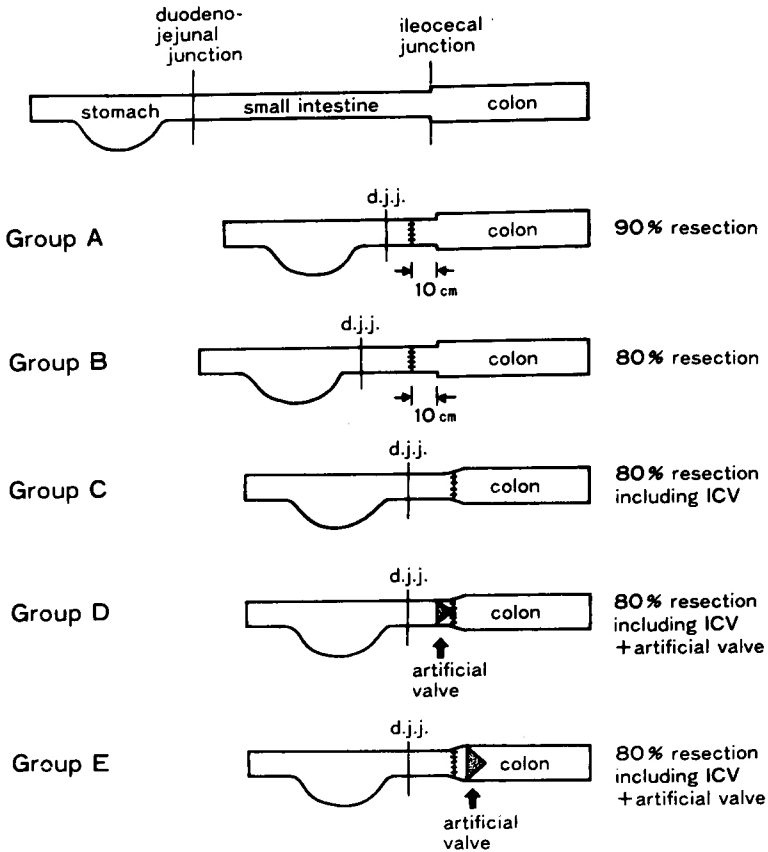
Fig. 1.　Diagram of operative procedures of 5 surgical groups
　　　　d.j.j.: duodeno-jejunal junction,　　≢: anastomosis
　　　　▷: artificial valve,　　ICV: ileocecal valve

artificial valve was formed 5 cm orad to the jejuno-colonic anastomosis.

Group E :　8 dogs, 80% small bowel resection, including the ileocecal valve. An artificial valve
　　　　was formed 5 cm aborad to the jejuno-colonic anastomosis.

The animals were given only water for 6 hours preoperatively. Intraoperatively the dogs were given intravenous fluids (*Hartman*'s solution) 100 ml/kg.

The animals were anesthetized intravenously with 25 mg/kg pentobarbital sodium. The peritoneal cavity was entered through a mid-line abdominal incision by clean operation.

Intestine length from the duodeno-jejunal junction (ligament of *Treitz*) to the ileocecal junction along the anti-mesenteric border was measured using a plastic ruler.

All animals underwent a small bowel resection with or without resection of the ileocecal valve. Following resections the animals in groups A, B and C received end-to-end anastomosis by layer-to-layer method using 3-0 Dexon sutures. Animals in groups D and E, following resection, underwent creation of the artificial valve.

## Operative technique for the artificial valve

The vas recti of the mesentery were divided. Seromuscular layer was detached from a lengh of an intestinal segment equal to its diameter at the jejunum and half at the ascending colon. The proximal segment up to the denuded segment was invaginated to the distal intestine (Fig. 2 and 3) and the raw edge of the distal part was sutured to the seromuscular layer of the proximal part with interruped 3-0 silk sutures. Then the enteron and the mesentery were sutured using approx. 6 stitches to prevent transit obstacle by adhesion or bend at the valve plastic site and valve dehiscence.

The abdominal cavity was closed using two layers of interrupted sutures. Postoperatively, the animals were immediately given water per os, followed by a chow 12 hours later. Intravenous fluid administration was not performed.

## Measurement

Body weight

Body weight was measured prior to operation, immediately after operation and at weekly intervals thereafter.

Stool assessment

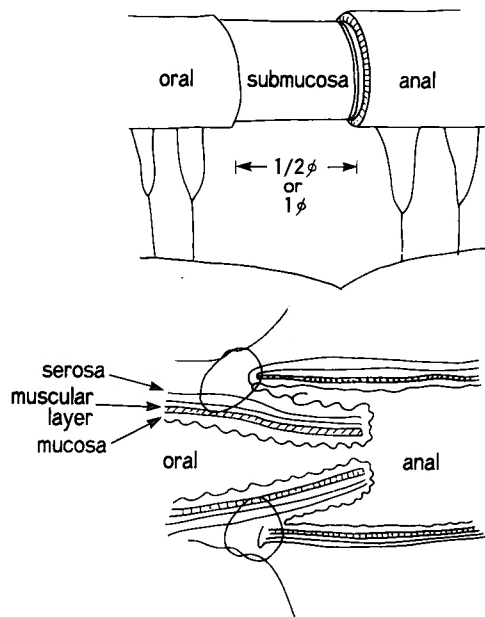Stool consistency was observed every three to four days.



**Fig. 2.** (upper) Artificial intestinal valvuloplasty.
The seromuscular layer was detached from a length of an intestinal segment equal to its diameter at the small intestine and half at the colon. Only vasa recti in the ablated portion were cut off.
(lower) Artificial valve cross section. Note the rupture at both the proximal and distal ends of the intestinal muscular layer; the serosa backed with mucosa is on the proximal side.
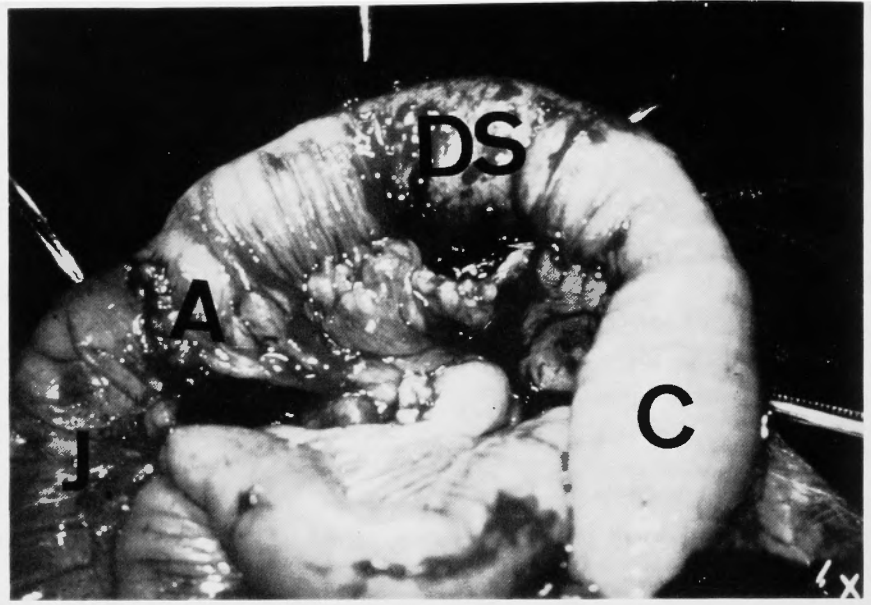
**Fig. 3.** Photogram of the artificial valve formation befor invagination in group E.
A ・ jejunocolonic anastomosis
C ： ascending colon
DS: denuded segment (both muscle layers removed)
J　 jejunum

Laboratory data

Red blood cell count, hemoglobin and hematocrit levels, electolytes, total protein and albumin concentration, total cholesterol level and triglycerides were measured preoperatively and again 15 weeks after operation.

Morphological Studies

Microscopic examination by hematoxylin-eosin stain was performed at death or 15 weeks after operation.

# Result

**Mortality**

In group A, 3 animals with severe diarrhea and weight loss died at 6, 16, and 27 days, while in group D, 2 dogs with severe diarrhea and weight loss died at 18 days, the remaiing animal survived.

After 5 weeks mortality was zero% in group B, 20% in group C and 12. 5% in group E. After 10 weeks, cumulative mortality was 12. 5% in group B, 40% in group C and 25% in group E. During this period, death in group C dogs was related to progressive cahexia with diarrhea characterized by excessive weight loss, while death in group E dogs was related to abdominal wall infection and diarrhea. After 15 weeks, mortality was 12. 5% in group B, 50% in group C and 25% in group E. (Fig. 4)
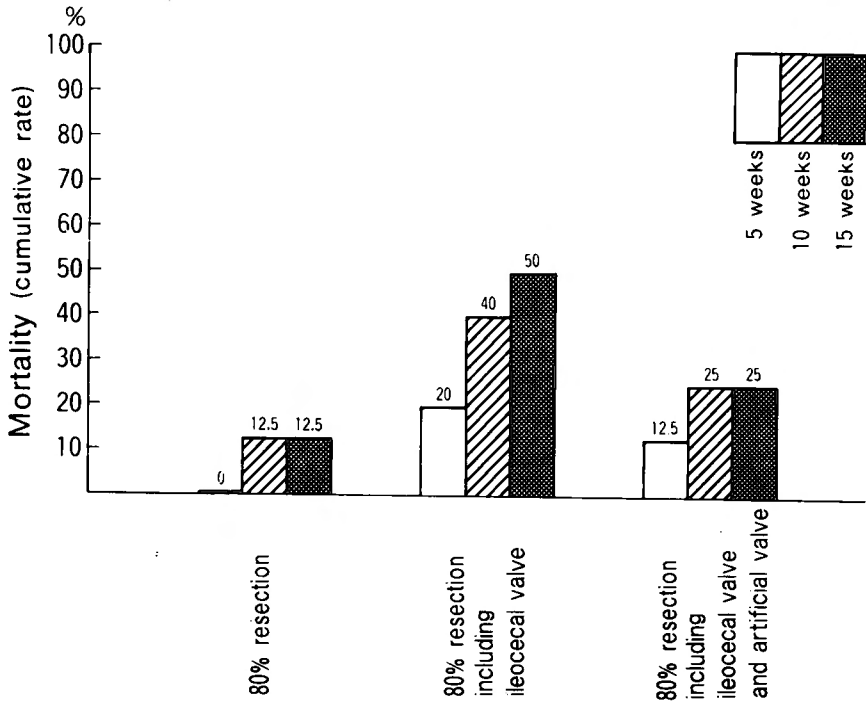
**Fig. 4.**   Mortality
In the 80% resection group, no dogs died during the 10 weeks after operation. The mortality rate was 50% in the 80% resection with resected ileocecal valve group and 25% in the artificial valve group.
Groups A and D were excluded due to the small number of cases (n=3).   In group A (90% resection), animals died at 6, 16 and 27 days.

The valve in one animal from group E was disruped at autopsy, the time of disruption is unknown.   This case was removed from the assessment.

**Body weight**

The average mean weight in the postoperative period is plotted and shown in Figs. 5 and 6. The 90% resection group (A) and 80% resection including ileocecal valve plus jejunal valve group (D) were not plotted.

Group B showed a sharp drop during the first postoperative week, followed by a gradual gain. Average weight loss was about 13% of initial weight, and at 3. 5 weeks the average weight of group B exceeded the preoperative level. (range 2. 5~4. 5 weeks)

Group C also showed a sharp drop in the first postoperative week, followed by a plateau. Weight loss was about 22% and continued up to 7 weeks.   After 15 weeks, animals surviving in group C showed a mean weight loss of 7%.

Group E also showed a sharp drop during the first postoperative week, followed by a gradual gain.   Average weight loss was about 14% of initial body weight, and at 5. 5 weeks the average weight of group E exceeded the initial level. (range 2. 5~8 weeks)

Weight change did not correlate with remaining small bowel length or operation time (Table
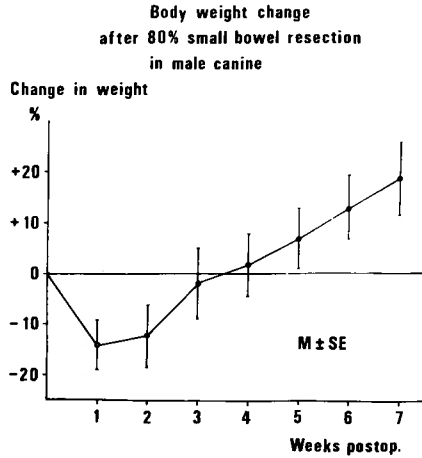
**Body weight change
after 80% small bowel resection
in male canine**

Change in weight



**Fig. 5.** Body weight changes after 80% small bowel resection (group B).
The average weight was lossed about 13% of the initial period, and exceeded the
preperative level at 3. 5 weeks.

2). Weight gain or loss seemed to depend most on the presence or absence of the ileocecal or artificial muscular valves.

## Stool assessment

Stool consistency was observed every three to four days. Stool frequency was not measured.

In group A stool consistency was watery, in group B semisolid (formed) to solid after 3 weeks, group C remained watery after 15 weeks, stool consistency in group E was semisolid after 15 weeks.

## Laboratory data (Table 3, Fig. 7)

No statistically significant changes were observed in red blood cell count, hemoglobin and
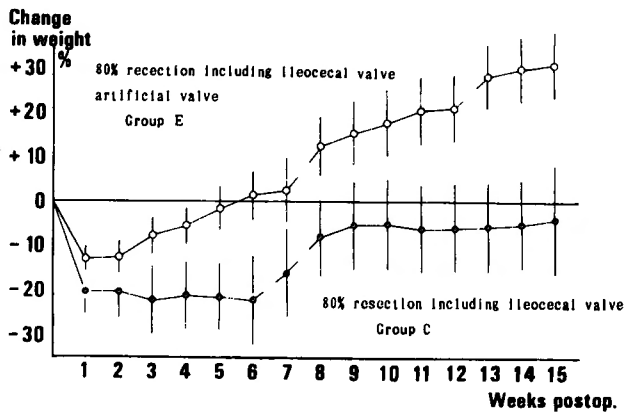


**Fig. 6.** Body weight changes of the 80% small intestine/ileocecum resection with or without the artificial valve fitting groups. (groups C and E)
Group C showed a sharp drop in the first postoperative week, followed by a plateau, while group E showed a sharp drop, followed by a gradual gain. At 5. 5 weeks the average weight of group E exceeded the initial level.

**Table 2.** The lenth of the small intestine prior to and after operation was comperable. There was no significant differences between each groups.

| | Length of small intestine | |
|---|---|---|
| | original (cm) | post resection (cm) |
| 80% resection | 218.3±23.39 | 43.7±4.68 |
| 80% resection including ICV | 226.6±15.99 | 45.3±3.19 |
| 80% resection including ICV +artificial valve | 216.7±13.74 | 44.7±3.59 |

hematocrit levels between groups C and E.  Serum sodium, potassium and chloride levels also showed no statistically significant changes.

A slight statistically significant drop was noted in total protein and albumin concentration in groups C and E.

The drop in total cholesterol levels was more marked in group C than in group E.  Statistically significant changes were also noted in triglyceride levels of both groups.

**Morphology of the residual intestine** (Fig. 8)

At the time of death or sacrifice for long term living animals of groups B, C and E, the most noticeable intestinal changes were thickening and dilatation of the gut.  Microscopically, increase in the number of vili and crypt length was noticed in the jejunum, but not in the colon. No significant differences between groups C and E were observed.

**Clinical observations**

Animals which survived the immediate trauma of operation did fairly well.  They began to

**Table 3.** Red blood cell, hemoglobin, hematocrit and electrolytes at 15 weeks post operatively.  There were no statistically significant changes in red blood cell count, hemoglobin and hematocrit levels between groups C and E.  Serum sodium, potassium and chloride levels also showed no statistically significant changes.

| | Group C 80% resection including ICV | Group E 80% resection including ICV+artificial valve | no operation |
|---|---|---|---|
| RBC 10⁴/mm³ | 625±196 | 611±125 | 545±82.4 |
| HB g/dl | 13.2±3.57 | 12.5±2.91 | 10.6±1.88 |
| Ht % | 40.0±9.85 | 37.5±8.44 | 33.1±5.08 |
| Na mEq/l | 152.6±4.42 | 149.7±4.17 | 148.8±3.22 |
| K mEq/l | 5.40±1.10 | 5.76±1.11 | 4.80±0.67 |
| Cl mEq/l | 112.2±9.64 | 107.8±5.11 | 108.1±4.61 |
| Ca mEq/l | 4.38±0.59 | 5.14±0.39 | 4.80±0.67 |
| Mg mEq/l | 2.30±0.40 | 1.98±0.26 | 2.69±0.27 |

T-P

g/dl

Alb

g/dl

T-CHO

mg/dl

TG

mg/dl
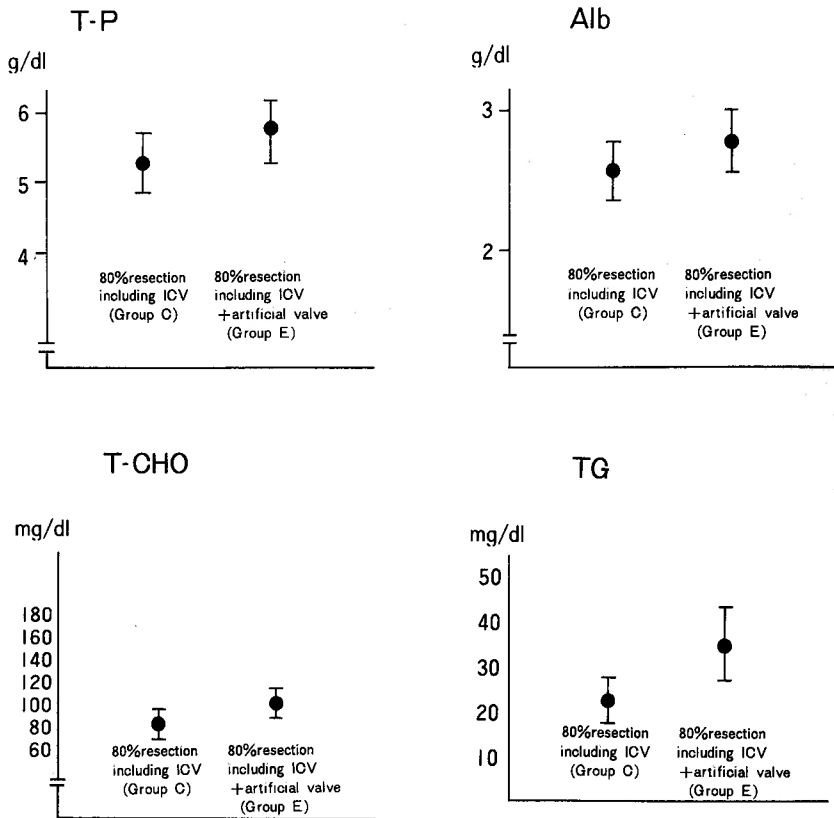
**Fig. 7.** Total protein, albumin, total cholesterol and trigliceride level at 15 weeks post operatively.
A statistically significant drop was noted in total protein and albumin concentration in groups C and E.
The drop in total cholesterol level was more marked in group C than in group E. Statistically significant changes were also noted in triglyceride levels of both groups.
T-P :      total protein
Alb :      albumin
T-CHO: total cholesterol
TG :      triglyceride
ICV:       ileocecal valve

drink wtihin 12 hours and to eat within 24, however most of dogs had a rather poor appetite.

The noses of animals which failed to regain body weight were dry, the coats lost the usual healthy sheen, and shedding or decubitus ulcers were common.

## Complication

The valve in one puppy from group E was disrupted at autopsy (Fig. 9). The dog grew favarably regaining its preoperative weight in three weeks.
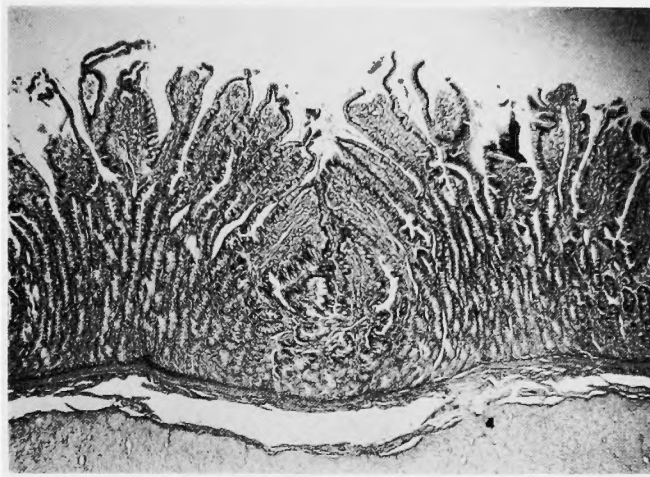
**Fig. 8–1.** Photogram of the jejunum, after 15 weeks in group E. (HE×10) Increase in villous hight and crypt depth was noticed.
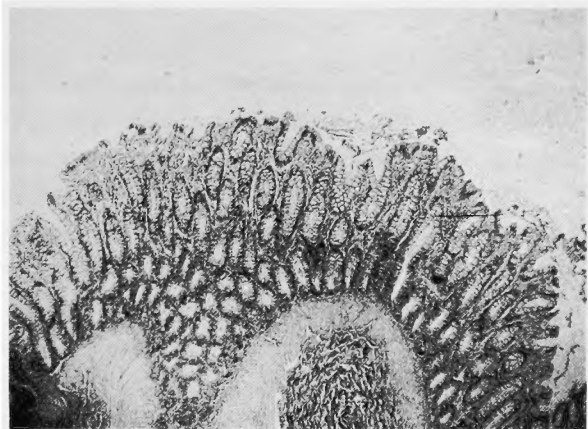


**Fig. 8–2.** Photogram of the colon, after 15 weeks in group E. (HE×10)

## Discussion

### Surgical Approaches to the short bowel syndrome

Many surgical approaches have been attempted in short bowel syndrome after massive bowel resection (Table 4). Some are already merely of historical relevance, while others are not yet clinically applicable.

Many attempts have been made to prolong transit time, the idea being to better absorption by longer contact of the intestine with the nutrients as a result of delayed transit. The valve or sphincter was also formed on the basis of this viewpoint and to prevent reflux from the colon to the small intestine.

Some attempts were made as well to directly increase the absorptive surface (induction of neomucosa and intestinal transplantation). Each will be described.

1. Vagotomy and pyloroplasty

**Fig. 9.** Disrupted valve in one animal from group E.

This technique aims at delaying gastric emptying and prevention of hypersecretion. *Federic*[29] noted a weight-loss prevention effect and good survival rate in dogs, the effect emerging 3 weeks after resection. Others reported clinical ineffectiveness[57] as well as a tendency toward incontinent stomach using this method[67].

Vagotomy and pyloroplasty are effective approaches to the hypersecretion inevitable after massive bowel resection and the subsequent acid-induced diarrhea[69], but the appearance of $H_2$-receptor antagonists[18,73] seems to have diminished their significance.

2. Reversed small intestinal segment

This metehod, having the oldest history, dates from *Mall*'s report in 1896[64]. *Hammer*[42],

**Table 4.** Surgical procedures for the short
bowel syndrome

Vagotomy and pyloroplasty
Reversed small intestinal segment(s)
Isoperistaltic small intestinal insertion
Colonic interposition
Interposed gastric tubes
Recircurating loops
Intestinal lengthning procedure
Induction of neomucosa
Electrical pacing
Intestinal transplantation
Valve or sphincter formation

*Singleton*[99,100], *Sako*[91] and *Stalgren*[102] found delayed transit time and improved intestinal absorption in their experiments, explaining that this was because the cephalad peristalsis in the reversed segment delayed transit in the proximal bowel and contributed to absorption of nutrients. Up to 1978, 29 clinical cases were reported[5] since *Gibson*[34] presented the first effective case in 1962.

Disadvantages of the approach are possible fatal obstruction dependent on the beazer formation, its lengh and individual variables, the risk of new processes added to the shortened small intestine and the impossibility of preventing bacterial ascent[55].

3.  Isoperistaltic segment insertion

*Torbey*[107] and *Singleton*[101] described this approach, believing that the isopeperistaltic "tonic" segment would slow the transit time. This technique has never been clinically used.

The disadvantages are the need for application of processes to the residual small intestine and inavoidable ascending infection.

4.  Colonic interposition

In this method, the colon is interposed in part of the jejunum[47] or ileum[46]. *Garcia*[30] clinically used it.

Antiperistaltic colonic interposition was presented by *Trinkle*[109], *Carner*[15] and *Lloyd*[59]. Its effect is controversial.

Complications, including fatal bowel obstruction, have been reported[59]. In cases with removed ileocecal junction, retrogressive infection is inevitable.

5.  Interposed gastric tube

Interposed gastric tube was reported by *Gerwig* et al.[33]. A segment of the stomach was fashioned into a tube and interposed antiperistaltically. No clinical use has been found.

6.  Recirculating loops

This approach was an attempt to make pass intestinal contents repeatedly through the intestinal tube by forming a loop at part of the small intestine, so as to prolong contact time with the mucosa and therby improve absorption[22]. In experiments, some found it effective[83], others found it ineffective[2,12]. It has been reported as clinically effective[13,62].

However, it has only historical relevance, in view of the procedural complexy and the frequency of complications[12].

7.  Lengthened intestine

In intestinal adaptation the increase is in terms of diameter, not length of the tubular cavity. Thus the intestine is lenghened, to double transit time, by dividing the residual intestine lengthwise into two parts which are then closed and connected, doubling transit time although the absorptive surface area remains unchanged[7]. Clinical trials reported by *Boeckman* et al.[9] show remarkable efficacy.

This is an interesting idea although any failure in such extensive manipulation of the valuable intestine would be irreparable.

8.  Induction of neomucosa

This is based on the idea of creating a new absorptive surface area in the intestinal tube. The small intestine is incised lengthways and sutured to the surface of the colonic serosa. It is

shown that a new mucosa is formed at this site and that enterocytes in this area contain the normal enzyme system[8]. This technology is not used clinically.

9. Electrical pacing

*Collin* and *Kelly*[17] took up this method. Electrical stimulation increases slow wave frequency in the intestinal tube, creating a larger absorptive capacity. This was said to affect not only retrograde, but also forward pacing[36] ; however it is not clinically used.

10. Intestinal transplantation

Some clinical cases have been reported[58,81]. The survival period was a maximum 76 days. In the near future, the situation of parenteral nutrition vs. transplantation may become that of renal dialysis vs. renal transplantation.

## Length of Resected Intestine

Dogs from whom 80% of intestine was resected together with the left ileocecum (group B) initially lost weight, then slowly regained it. By 13 weeks they had increased their preoperative weight by 50% under normal conditions of nutrition, with glossy fur and wet nose. Even the younger dogs were thought capable of survival and growth. On the other hand, dogs undergoing 90% resection (group A) died early and seemed difficult of survival without positive management, including hyperalimentation. *Schiller*[96] reported that experimental dogs barely withstood 90% intestinal resection, dying within 7 weeks. Other investigators[12,15] obtained similar results; *MacBy*[62] found some dogs surviving 85% resected small intestine. *Haymond*[44] first reported 50% to be the safety limit, taken from statistical analysis of 257 cases. This limit has been raised with the progress of intravenous alimentation. *Jordan*[48] regarded 50% or less resection as moderate, 50-80% extensive and 80% or more as radical, finding that in the radical group, most survived, though 23 of 44 animals were morbid. Massive bowel resection was defined as 2/3 or greater[105] (2m or more)[5] resection of the small intestine in adults and a residual small intestine of 75 cm or less in children[87], a length corresponding to 50-70% or more resection of the small intestine.

Surviving cases with resection of the entire small intestine have been reported[10,20], since living cases with a few inches of residual small intestine were presented[3,16,66,68,108,112] and parenteral nutrition was advocated by *Wilmore* and *Dudrick* in 1968[114], that is, survival was proved possible to some extent[10,97] even with complete resection, depending on the treatment. These cases, however, were assumed to be difficult of lengthy survival, owing to liver changes resulting from hyperalimentation[63,89] as well as from the massive bowel resection[23,41,78].

In view of the above, intestinal transplantation may be one of the answers.

## Intestinal Adaptation

In the 80% small intestine resection group (group B), the mortality was zero% 5 weeks after operation, 12.5% at 10 weeks and zero over the remaining period of observation (11 to 15 weeks). The body weights decreased by 13% early after operation returning to prepoperative levels in 2.5 to 4.5 weeks (3.5 weeks on average). *Pullan*[82] divied intestinal adaptation into three stages ; immediate postoperation (Stage I) ; recovery/adaptation (Stage II), characterized by frequent diarrhea, weight loss and shortened transit time ; and stabilized (Stage III). The animals

in group B rapidly passed through the first and second stages and entered the final stage by 5 weeks after operation.

On the other hand, animals with 80% small intestine and ileocecum resection (group C) had cumulative mortality rates of 20%, 40% and 50% at 5, 10 and 15 weeks, respectively. The weight loss reached 22%, remaining 7%, on average, even in those dogs that survived beyond 15 weeks. The stool remained watery at 15 weeks and was first semisolid at 25 weeks, exceeding the period of observation. This shows a more prolonged *Pullan*'s second stage in this group than in group B and suggests that the ileocecum plays an important role in intestinal adaptation.

Intestinal adaptation after massive bowel resection, completed in Stage III via Stage I and II, has been morphologically and physiologically investigated. In morphology, the growth of villi[28,61,72,74,80,95,98,115], the increased depth of crypts[74,113,117], the increased diameter of the tubular cavity[50,95,115], and the growth of microvilli[52,90] were presented, and are acceptable, with some objections[25,54]. In this study, clear differences were not found microscopically in living dogs in each group after 15 weeks.

Shortened transit time and accentuated migrating myoelectric complex are regarded as intestinal physilogical adaptations[50]. In *Pullan*'s second stage, therefore, physiologic diarrhea should be taken into consideration as well as that hitherto regarded as a result of gastric hypersecretion[29], disturbance of lipid absorption[79] or colon irritation caused by failure of bile salt reabsorption[111,117], in cases of resected ileocecal valve.

## The Role of the Ileocecal Valve

Clear differences were observed in mortality, weight curves, stool assessment and blood chemistry between the 80% small intestine resection (group B) and 80% small intestine/ileocecum resection groups (group C). Group B showed a significant difference in mortality (12.5%) in comparison with group C (50%) while in group C the weight loss was 22% with less likelihood of recovering it (7% loss remaining even in survivors beyond 15 weeks). In these experimental models, these results can be regarded as dependent on the presence or absence of the ileoccecal valve, even though in group B preserved 10 cm of the terminal ileum was preserved, where as group C kept 10 cm of the jejunum instead.

In the digestive tract, digestion and absorption are efficiently performed via the constriction mechanism, that is, modulation of content transmission and prevention of reflux via valve or sphincter in situ. Constriction activity shows some differences between the oral and anal sides, in particular at the esophagocardium and ileocecum. The constriction action is strong at these sites.

In the ileocecum, the constriction mechanism is comprised of the ileum, running into the boundary of the cecum, and the ascending colon, whose diameter is about three times that of the ileum. Valve function is extremely excellent in this area, with a transition pressure of 20 cm $H_2O$ or less and a reflux prevention pressure of 40 cm $H_2O$ or more[118].

*Kellogg*[51], one of the first surgeons to investigate the ileocecal valve, said that it "not only prevents reflux of material from the colon into the small intestine but also regulates the movement

of material from the small intestine into the colon (in a manner quite analogous to the action of the pylorus in passing digesting food from the stomach into the small intestine)".

*Stalgren*[102] described "jejunal hurry" due to unrestricted jejunal motility in resection of the ileum including the ileocecum and *Singleton* et al.[101] indicated that neither 80% small intestine resection nor ileocecum resection resulted in differences in absorption or transit, but the combination of both resections led to marked abnormality of absorption and rapid transit. *Reid*[84] studied 90% small intestine resection and valvotomy in experimental animals and found higher mortality and less weight recovery in the valvotomy group.

In 17 clinical cases, *Cosnes*[19] found that patients with the ileocecal valve remaining had transient and moderate malabsorption whereas those with the ileocecum resected showed severe and permanent malabsorption.

*Ricotta*[88], *Weser*[111], *Ogilvie*[76] and *Kalser*[49] pointed out short transit in resection of the ileocecal valve, which accurately reflected the modulation of transit or flow through the small intestine by the valve.　The one problem is whether such regulation comprises merely the retardance of nutrient passage, that is, whether the valve merely interrupts the flow, or whether it functions as a true valve or sphincter.

It is noteworthy that the ileocecal valve not only prolongs transit but also opens and closes repeatedly without small intestinal stasis[24].　The valve opens and shuts not only with changes in internal pressure, which is most important, but in reflecting the pattern of more proximal activity, as does the esophagocardium[106].

The function of the ileocecal valve is effective in preventing material rich in bacteria from refluxing from the colon into the small intestine.

*Richardson* and *Griffen*[39,85] found 76 times the bacterial colonies and severe weight loss in dogs with resected ileocecum and believed that the loss was caused by colonization in the small intestine resulting from the inflow of bacteria.　Similar findings were presented by *Gazet*[32], *Mallory*[65], *Cumming*[21] and *Mitchell*[70].　Colonization and shortened transit time[53], or the bacterial contamination itself[71], might prevent absorption.　Colonization in the residual small intestine was reported to have increased deconjugated bile acid and to have promoted the inhibition of protein, carbohydrate, electrolyte, vitamin $B_{12}$ and folic acid absorption, as well as to have encouraged bacterial diarrhea[11,111,117].

As described above, the ileocecal valve functions in the regulation of transit and as a bacterial barrier.　These are important functions, particularly in massive bowel resection.

*Reid*[84] stated that the clinically critical length for survival was 40 cm of the small bowel if the ileocecal valve was removed. *Benson*[6] discribed that if the valve was preserved, 30 cm of the small intetine was sufficient for suvival and less than 30 cm made survival difficult ; if the valve was not preserved, however, even 30 cm of the intestine was not enough for survival. *Wilmore*[116] reviewed English references and reported that, of 50 neonates with 75 cm or less postoperative residual small intestine, 5 with 15 to 30 cm of intestine and no ileocecal valve died but 8 of 15 with the same length of the intestine and the valve survived.　All neonates survived, regardless of ileocecum resection, in whom at least 40 cm of the small intestine was preserved.

In addition, *Gil-Vernet*[35] adjudged the ileocecal valve area "an ideal substitute for ureter and bladder" in urological surgery ; *Lee*[56] substituted the valve area for the stomach with good results, and *Endo*[26] succeeded in using it in biliary atreasia. Judging from the above, the valve seems to be extremely valuable in reflux prevention and flow regulation.

Considering that the valve not only works anatomically but is subject to nervous control[27,31] and may be affected by gastrointestinal hormones, particularly secretin and gastrin[4], it may seem strange that it functions well when transplanted to other sites. However, this can be explained on the basis of internal pressure changes, which is the most important factor in the funtion of the valve.

## Evaluation of Artificial Intestinal Valves

Several differences were found between groups C and E (combined ileocecum resection and artificial valve graft): mortality, 50% in group C, 25% in group E ; initial weight loss, 22% in group C and 14% in group E. The initial weight loss was found in both groups, to different extents, but weight did not return to the preoperative value (remaining 7% below preoperative) in 15 weeks, and there was no sign of increase, in group C, whereas it increased slowly and returned to the preoperative average 5. 5 (2. 5 to 8) weeks after operation in group E. Further, the stool 15 weeks after operation was watery in group C, while smisolid in group E.

In terms of laboratory data, the artificial intestinal valve graft group showed better results for serum protein, albumin, cholesterol and triglyceride. This means that the artificial valve graft clearly promoted intestinal adaptation.

This is probably partly because the artificial valve regulated the flow of digested material and prolonged the transit time, and partly because it prevented colonization in the small intestine. The artificial valve graft was found to have the same effect as the preserved ileocecal valve.

*Stahlgren*[103] pointed out that transit time was prolonged merely by obstruction. The ileocecal valve opens and closes mainly owing to changes in internal pressure, with a transition pressure of 20 cm $H_2O$ or less and a reflux pressure of 40 cm $H_2O$, preventing stasis at the proximal (that is, the small intestinal) side. The artificial intestinal valve used in the present study consisted of one layer each of circular and longitudinal muscles, both sides of which were covered by mucosa. The transit (average 26. 4 cm $H_2O$) and reflux (average 44. 5 cm $H_2O$) pressures were almost equal to those of the ileocecal valve[75,94].

Radiologic examination in clinical cases proved that the prosthesis did not cause obstruction,

**Table 5.** Valve or sphincter formation after massive bowel resection

| Glassman | 1942 | Hidalgo | 1973 |
|---|---|---|---|
| Stahlgren | 1964 | Grosfeld | 1974 |
| Schiller | 1967 | Careskey | 1981 |
| Ackroyed | 1969 | López-Pérez | 1981 |
| Waddel | 1970 | Ricotta | 1981 |
| Grier | 1971 | Diego | 1982 |
| Richardson | 1972 | | |

but opened and closed[43]. It may have satisfied the requisite of *Ricotta*[88], "prevention of stasis in the small intestine".

In 1913, *Kellogg*[51] attempted to regulate digestive flow and prevent reflux from the colon to the small intestine when the ileocecal valve was removed in intestinal surgery. In 1942, *Glassman*[37] first used a substitute for the valve in massive intestinal resection.

*Satomura*[93] listed four essential functions for valve mechanisms intervening in the enteron; (1) passes material in the peristaltic direction under a certain pressure, (2) prevents reflux in the antiperistaltic direction up to a certain pressure and allows reflux over that pressure, (3) prevents organic stenosis, (4) maintains narrower tubular cavity on the proximal side than on distal side of the valve or presents no caliber change. Additional important conditions are (5) a constant direction of digestive flow at a steady state, (6) long-term competence[92], and in massive intestinal resection, (7) no manipulation of the residual small intestine. The requirement described in (4) should be strictly investigated because massive resection will lead to expansion of the cavity of the residual intestine, particularly the upper tube, as a result of intestinal adaptation.

*Glassman*'s artificial valve is a mucosal intussuscepted valve placed 20 cm proximal to the ileocolostomy site. Unfortunately, the mucosal valve shows inconstant direction because it is not supported by the muscle layer but contracts without long-term competence finally becoming merely stenotic. In addition to these, the valve presents the following disadvantages : placement in the residual intestine probably causes colonization in the area distal to the valve and the precious intestine is likely to be damged.

Here, pioneering trials will be reviewed. (Table 5) *Stahlgren*[103] used "jejunal pleating" for plication of the partial jejunum and partial stenosis. This result cannot be truly called a valve.

*Schiller and DiDio*[86] invented a valve mechanism in which the serosa and longitudinal muscular layer were ablated and the circular muscle was preserved. Obviously, the circular muscle plays the primary role of the sphincter. Raised tonus of the muscle causes contraction and closure of the tube ; the contracted longitudial muscle shortens the longer diameter of the intestine and leads to relative expansion of its inner diameter. Ablantion of the longitudianal muscular layer facilitates these processes. Another key point of the sphincter action is passive opening by raised internal pressure. This may become a problem with *Schiller*'s valve.

*Waddel* et al.[110] performed jejunocolostomy and anti-telescoping anastomosis in 3 clinical cases. Two showed decreased frequency of diarrhea and weight gain, whereas one needed valve resection owing to intestinal obstruction.

The valve was aborad, and is thought to be better for transit in the anti-peristaltic direction than in the peristaltic direction. It is feared that bowel obstruction will inevitably occur. The obstruction may cause delay in transit, which decreases absorption[103]. The valve may be incompetent for shifting microorganisms upward.

*Grier*[38] formed a nipple valve of antiperistaltic direction in the residual small intestine of dogs with 80% intestinal resection. The valve is aborad, like *Waddel* et al. 's, and merely seems to accelerate obstruction.

*Hidalgo*[45] re-investigated a mucosal valve similar to *Glassman*'s and regarded it as effective. *Suruga*,[104] and coworkers, a Japanese surgeon, operated in a clinical case for which there was no long-term follow-up report ; even his co-worker was doubtful of the efficacy of the mucosal valve.

In resection of the small intestine and 50% of ileocecum, *Richardson*[86] prepared and bacteriologically investigated an antiperistaltic reversed segment (6 cm long), a *Schiller*'s sphincter and an *Ackroyd*'s mucosal valve[1]. He reported that the sphincter and valve were effective.

*Grosfeld*[40] resected a 2. 5 cm circumferential segment of longitudinal muscle and anastomosed both sides to prepare a valve. This was a type of mucosal valve and *Schiller* sphincter.

*Careskey*[14] first used small animals in his experiments ; this permitted the use of large numbers of animals. However, the valve itself was of the *Grier* type and its inherent defects remained.

*Lopez-Perez*[60] investigated an ileal intussuscepted valve for use after massive bowel resection. A nuit comprising 1 cm and 1. 5 cm ablations of seromuscular layers connected to the ends of a 3-3. 5 cm of an ileal segment was intussuscepted in the distal (or intestinal) direction and sutured. Thus, the valve consisted of two layers of muscle, but the continuity of the muscular layers was broken at the base of the valve.

*Riccota*[88] presented a substituent for the ileocecal valve that was formed as a 4 cm nipple valve by folding outward one end of the small intestine (after ileocecum resection) and intussuscepting and inosculating it into the colon. He reported the results of a clinical case and experiments involving dogs, stating that the valve was effective against mortality and weight loss. Conical in structure, the valve is well-designed to prevnent divarication, a defect of conventional conical valves[77], but requires a bit of improvement in ease of causing stenosis.

As complication, valve disruption was found in one puppy (Fig. 9). The puppy grew favorably, however, regaining its original weight in three weeks and 170% of that weight in 15 weeks. This case showed the high efficacy of the artificial valve. It was not known when the valve was disrupted. If it occurred early, earlier aid in intestinal adaptation would lead to better results. If so, the present view with regard to postoperative mangement should be changed. This valve is harder to break than previous conical valves, because of the monolayer muscle in the valval lip. However strict care should be taken in handling the valve, such as when affixing it to the mesentery.

## Location of Artificial Valve

No conclusions can be drawn because the groups contained only a few animals (n=3). However, two of the three animals in group D (jejunel valve fitting) died at *Pullan* Stage I (18th day) ; one survivor lost up to 38% of its weight and did not regain it (−25%) even 10 weeks after the operation, although the artificial valves were placed in the residual enteron in both group D and E. This forces us to discuss the location of the valve.

Although possible colonization in the section between the intestine distal and the valve decreased the effective absorption area, the length of the section was only 5 cm. Are such effects found in a postoperative period as short as 18 days? It is also difficult to believe that partial ablation of the intestinal muscle layer caused mixing disorder. Ultimately, the only explanation

may be obstruction at the location of the valve.

## Conclusion

As described in the previous paper, ileocecal lesions were enucleated from patients (as many as 9 of 10) undergoing massive bowel resection.  These statistics induced us to apply artificial valves to this pathology.

For experiments, 46, 3-6 kg young dogs were devided into 5 groups ;

> 90% resection group (n＝3)
>
> 80% resection group (n＝8)
>
> 80% resection plus ileoceccal valve resection (n＝10)
>
> 80% resection with ileocecal valve resection plus jejunal valve fitting* (n＝3)
>
> 80% resection with ileoceccal valve resection plus colonic valve fitting* (n＝8)

Mortality, weight, stool apperance, blood chemistry, morphology and clinical observations were obtained.

The 80% resection group showed good postoperative adaptation, while the 80% resection plus ileocecal valve resection group showed poor adaptation, results which seemed to depend on the presence of the ileocecal valve.

Significant differences were found in weight, mortality, stool appearance and blood chemistry between the artificial valve (colonic) fitting group and the ileocecal valve resection group.

The artificial intestinal valve as well as the ileocecal valve played an important role after massive bowel resection.

In massive resection, the ileocecal valve should be preserved to the utmost.

The artificial valve is useful in cases of ileocecum resection.

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**和文抄録**

# 腸管大量切除に関する基礎的，臨床的研究
## —特に人工腸弁の効果について—
### 第2編　腸管大量切除における人工腸弁に関する実験的研究

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　腸管大量切除は新生児外科においては，全結腸無神経節症，腸閉鎖，壊死性腸炎，腸回転異常症，等の場合に，成人外科においては，潰瘍性大腸炎，クローン氏病，腸管膜動脈血栓症，あるいは悪性腫瘍の際に行なわれる機会が増加している．その結果として，下痢，吸収障害，体重減少が持続し，社会復帰が困難な場合も多い．特に回盲部が合併切除された場合その傾向が著しい．

　回盲部合併切除の頻度の高いこと，管理の困難な点より，回盲弁の働きを代償する人工腸弁をこの病態に応用した．

　46頭の 3〜6 kg の幼犬を用いて，これを5群に別け実験した．

　内訳は

　90％切除群　n＝3

　80％切除群　n＝8

　80％切除＋回盲弁切除群　n＝10

　80％切除＋回盲弁切除＋空腸腸弁群　n＝3

　80％切除＋回盲弁切除＋結腸腸弁群　n＝8

であり，死亡率，体重変化，便性状，血液化学，形態的変化，臨床所見をとらえ，以下の結果を得た．

　①80％切除群は術後の adaptation は良好

　②80％切除＋回盲弁切除群は adaptation 不良であった．

　③上記の差は回盲弁の存在にあると考えられた．

　④人工腸弁付加（結腸）群と回盲弁切除群との間に体重，死亡率，便性状，血液化学検査において明瞭な差を認めた．

以上のことより，大量腸管切除が行なわれる場合，回盲弁切除は極力避けるべきであり，やむなく，回盲弁が切除される場合人工腸弁の応用が有用である．