Jejunal Feeding

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Jejunal feeding may be resorted to when oral ingestion or intragastric tube feeding are not feasible. It has the important advantage over intravenous alimentation that it enables the patient to take a dietary consisting of all types of nutriments, and usually provides a higher caloric intake and a more positive nitrogen balance. Jejunal feeding is especially indicated to correct malnutrition resulting from obstruction of the outlet of the stomach or duodenum by malignancy or other disease, from failure of a gastroenterostomy stoma to function after gastric resection, and from duodenal fistula; it has also been recommended in the management of gastrocolic fistula. It may also be used in patients with protracted gastric vomiting secondary to diseases of the central nervous system.

Physiologic Considerations

One of the functions of the stomach is that of a reservoir. It normally retains an ingested meal for about $2^1/_2$ to $3^1/_2$ hours, depending on its composition, and empties at an estimated rate of 10 ml per minute. During the time the food remains in the stomach it is mixed with gastric secretions and partially digested. In addition, fluid enters the stomach from the blood stream for the dilution of those food substances which possess high osmotic properties so that they are acceptable by the small intestine. The extent to which gastric content may be diluted under certain conditions is indicated by the observations of Ravdin and associates[1] who found that glucose solutions of various concentrations, when introduced into the stomachs of dogs, were diluted to a volume as much as $2^1/_2$ times that originally introduced within a period of an hour. Retardation of gastric emptying time in humans as a result of the presence of barium meal mixtures containing 50 per cent glucose was reported by Pendergrass *et al.*,[2] and as a result of introduction of concentrated meals by Shay and co-workers.[3]

It has been firmly established that dilution of hypertonic materials introduced into the small intestine occurs in a similar fashion. Abbott, Karr, and Miller[4] found that the volume of solution aspirated from a loop of human jejunum isolated by means of an intubation procedure increased directly as the concentration of the solution introduced, a 50 ml volume of 43.2 per cent glucose solution increasing to 100 ml in 15 minutes. Considerable increases in volume of solution removed from a loop of jejunum, similarly isolated, following the introduction of a 10 per cent solution of protein hydrolysate or of a saturated solution of sodium sulfate also have been reported.[5] The dilution of barium mixtures containing hypertonic glucose solutions has been demonstrated radiologically.[2] "The intestinal stream produced a cloud effect in the jejunum as though the hypertonic solution caused the mucosa to pour out fluid in an attempt to dilute the opaque medium."[2] The fluid for the dilution enters the lumen from the blood stream of the intestinal wall. Its loss from the vascular system may be reflected in a decrease in blood volume.[6] In their experiments, Abbott and associates[4] noted that the propulsive activity of the small intestine increased with concentrations of glucose above 5.4 per cent. An increase in intraluminal pressure and in motility following the introduction of hypertonic solutions has been recently demonstrated.[7] Thus the introduction of hy-

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pertonic substances into the intestine can give rise to disturbances in physiology, some of which may be reflected in clinical symptoms such as vomiting, manifestations of the dumping syndrome, intestinal cramps, and diarrhea. *Consequently, one of the important considerations in jejunal feeding lies in the osmotic properties of the materials to be introduced. Such materials should be as nearly iso-osmotic as possible, or else they must be administered very slowly.*

Another important consideration of the type of material introduced into the intestine lies in the nature and percentage of fat introduced. For example, whole milk, though having an osmotic pressure approaching that of body fluids, may also give rise to flatulence, cramps, and diarrhea. These have been ascribed to a specific effect of the size of the fat particles[8]; however, an increase in the osmotic properties of the milk which occurs when its proteins are partially digested to smaller molecules may also play a role. *Most patients cannot tolerate more than 6 per cent crude fat for prolonged periods,*[8] *though proportions somewhat larger than this may be tolerated if administered in emulsified form.*[9]

Methods of Administering Jejunal Feedings

The choice among the various means of introducing nutrients into the jejunum depends primarily on the indication for so doing. A tube may be passed into the jejunum by the naso-gastric route, via the duodenum if gastrointestinal continuity is intact; this procedure is an obsolete treatment for duodenal ulcer, and a current one for the management of intractable gastric vomiting on a cerebral basis. A simple single lumen #16 French rubber tube, or one of the more recently available plastic tubes may be used. A 3 mm polyvinyl tube is soft, non-irritating, durable, and inconspicuous, and may be used for long periods without changing. It is not, however, radio-opaque, and cannot be manipulated under fluoroscopic guidance as readily as the rubber tube. Visualization can be accomplished by filling the lumen with a thin barium water suspension and clamping the nasal end. The attachment of a small mercury-filled rubber bag by means of a silk suture threaded through the lumen of the tube will aid in the passage of the tip of the tube into the jejunum.[10] A hypodermic needle hole at the proximal end of the bag prevents the accumulation and expansion of gases, tending to keep the tube from being propelled downstream.

This technique may also be attempted in the management of a non-functioning gastroenterostomy, passing the tube directly through the anastomosis. Unless the tube is put in position at the time the anastomosis is fashioned, however, it usually proves exceedingly difficult to pass when it is needed most. This is also true of duodenal fistula.

In general, therefore, jejunostomy is an operative procedure. With the abdomen open, the very great advantages in keeping the tube out of the oropharynx and esophagus, when it is likely to be in place for a considerable period, lead the surgeon to exteriorize it through the abdominal wall.

The tube may be introduced directly into the jejunum by the Stamm or Witzel[11] technique, or it may be inserted into the stomach and threaded into the jejunum, a method of particular advantage when the double lumen tube is used. In either event, the operation is basically a simple one and should not be complicated by elaborations. Local anesthesia may be used in a poor-risk patient. Any incision allowing the surgeon to identify the ligament of Treitz will give satisfactory exposure, but in view of the poor nutritional status of most of these patients, an incision should be chosen which will heal satisfactorily and be unlikely to disrupt. Reopening the previous wound is advantageous particularly in the case of non-functioning gastroenterostomy. A mushroom or bulbed catheter is unnecessary and increases the probability of partial obstruction. For a direct jejunostomy, the first segment of jejunum which will lie comfortably against the left upper abdominal wall is selected, the tube is introduced distally for a distance of 10 to 15 cm and secured by purse-string suture or a short Witzel canal; it is then brought out through a stab wound, drawing the jejunum up to the parietal peritoneum, and secured at the skin. When the double lumen tube is placed through a gastroenterostomy, the jejunum need not be opened. A gastrotomy is performed to inspect and palpate the stoma, any indicated unkinking is done, and the tube passed through into the intestine. Care should be taken that the holes in the proximal limb lie entirely within the stomach, so as to prevent leakage, and at the same time the tube must not be kinked by an excessive loop.

Such jejunostomies will close within 24 to 48 hours after removal of the tube. Although it has been suggested by Allen and Welch[12] that a jejunostomy be established at the time of gastrectomy, we have not used this operation as routine practice, feeling that it introduces a superfluous procedure in the vast majority of patients, and may, if used prematurely, delay the patient's alimentation by the normal route. For the same reason we abandoned some years ago the routine use of the double lumen tube passed through the anastomosis, with suction on the proximal limb and feeding on the jejunal side. This tube, however, is of great advantage in two situations: first, where the patient's nutritional condition is poor, so that the assurance of the ability to feed within a short interval after operation is more important than any impairment in the immediate function of the gastroenterostomy that may occur as a result of the use of the tube; and second, in the gastroenterostomy that fails to open. In the first instance, the tube is placed at the original operation either through the nose or directly through the abdominal wall; alternatively, a direct jejunostomy may be employed, with naso-gastric suction on a separate tube.

Non-functioning gastroenterostomy, however, poses a serious and challenging problem to the surgeon. The urge to intervene must be strongly resisted, since mechanical difficulties will rarely be found; it is our practice to wait at least three weeks in the average patient before considering re-operation. During this period the stomach should be kept empty, by continuous or periodic aspiration, and the fluid and electrolyte replaced. Gastric distension in itself will interfere with the opening of the stoma. Trials of oral feeding will of course be necessary, and attempts may be made to get a nasal tube into the efferent loop. Unfortunately, when fluid will not pass into the jejunum, a tube will rarely do so. In the few cases where exploration becomes mandatory, the double lumen tube of Abbott and Rawson[13] gives splendid results. The tube is so constructed that one limb may be used to aspirate gastric secretions and drainage from the afferent loop, and the other to introduce material into the jejunum, both foodstuffs and the aspirated digestive juices.

In other situations a direct jejunostomy may be advantageously combined with another operative procedure. In a patient with a ruptured esophagus, for example, material introduced into the stomach will commonly drain through the established thoracic esophageal fistula, tending to keep it open; feeding by jejunostomy offers the only alternative to division of the cardiac end of the stomach. We have treated several cases of duodenal fistula by performing a limited subtotal gastrectomy or even an exclusion procedure, placing a tube for aspiration in the duodenal stump, and using a jejunostomy for the return of the duodenal secretions and for alimentation until the gastroenterostomy is functioning.

Type of Feedings

The type of material to be introduced into the jejunum should be non-irritating, approximately neutral in reaction, free of harmful bacteria or their toxins, and should provide calories and the essential vitamins and minerals in adequate amounts. It should be inexpensive and readily prepared, easily digested and absorbed, and capable of being varied to meet individual requirements. It should not be excessively hypertonic and when unavoidably so, must be dripped in at a slow rate in order to avoid the undesirable sequelae of too rapid entrance of hypertonic material into the small intestine. The feeding should be of low enough viscosity to drip by gravity through the tube.

Food mixtures which can be administered vary from ingredients obtainable in most household kitchens to special commercially available preparations. Some of the latter are considerably less expensive calorie for calorie than ordinary foods and can be prepared more conveniently and in a shorter period of time. In order to obtain consistently good results with jejunal feeding, individual differences may require variation in mixtures and schedules.

Assuming that the patient who is to be fed by jejunum has just been subjected to operation and has a jejunostomy opening for this purpose, the regimen as outlined by Boles and Zollinger,[8] subject to modification when indicated, may be employed:

(1) *First day:* For 12 to 18 hours after creation of the jejunostomy, nothing is introduced into the tube.

(2) *Second day:* During the second day 50 ml of a 5 per cent solution of glucose in water are introduced at hourly intervals.

(3) *Third day and thereafter:* By the third day, 100 ml of the 5 per cent glucose solution are usually tolerated at hourly intervals. When bowel activity has been restored as evidenced by presence of intestinal peristalsis on ausculation, consideration can be given to the administration of milk. Although whole milk introduced directly into the jejunum may produce cramps and diarrhea, homogenized milk may be better tolerated, presumably because of the relatively minute fat particles.[8] Starting with quantities of 50 ml of milk hourly, the amount is gradually increased during the next 1 to 3 days to 200 ml every three hours. The administration of water, glucose, and important electrolytes is continued.

Additional calories may be administered in the form of fat, carbohydrate, and protein, depending on indications.

Fat

Attempts to increase the caloric content of the feedings by increasing the percentage of fat usually fail. Most patients cannot tolerate more than 6 per cent crude fat for prolonged periods.[8] The amount of fat which can be tolerated may occasionally be increased by administering it in emulsified form,[9] but when so administered it should be given by slow drip.

Carbohydrate

Additional carbohydrate can be supplied by adding 60 g of hydrolyzed starch to each 1000 ml of milk. It is preferable to use carbohydrate in the form of starch hydrolysate or Dextrimaltose,® as these substances are less osmotically active than equivalent concentrations of glucose or sucrose solutions. The latter are tolerated if iso-osmotic concentrations of 5 per cent are not exceeded; when they are, they may have to be administered by slow drip.

Protein

Additional protein may be supplied by adding 60 g of protein hydrolysate to each 1000 ml of milk. If the resulting mixture of milk, starch hydrolysate, and protein hydrolysate when introduced into the tube in large amounts, i.e. 200 ml every 3 hours, causes abdominal cramps and diarrhea, a continuous drip at a slow rate should be instituted, the number of drops per minute being determined by the way the mixture is tolerated. Usually a rate of 40 drops or less per minute is satisfactory.

Vitamins

The caloric intake should be supplemented with the daily requirement of vitamins as recommended by the Food and Nutrition Committee of the National Research Council. These should include vitamins A, D, and C, and the members of the B complex. During the period when very little except glucose and water is being administered, vitamin C and the important members of the B complex can be injected parenterally or the contents of a gelatin multivitamin capsule can be added to the solutions being introduced through the tube. Some satisfactory polyvitamin preparations are available on the market which disperse readily in aqueous solution and can be readily administered through a small bore tube. When intestinal antibiotics are being administered concurrently, vitamin K should be supplemented.

Electrolytes

Feedings of 2000 ml of milk or more will more than meet the daily basic body requirements for potassium. But if potassium loss is excessive, or if a deficit exists, 1 g each of potassium citrate, potassium acetate, and potassium bicarbonate dissolved in 8 ml of water can be introduced directly into the jejunostomy tube 3 or 4 times daily. This should replace all but the most abnormal losses of potassium.

Other electrolytes and minerals may be administered when desired, especially if diarrhea is excessive. A convenient preparation available commercially consists of a powder, 80 g of which per quart of water yields electrolytes in terms of mEq per liter as follows: sodium, 50; potassium, 20; calcium, 4; magnesium, 4; citrate, 35; sulfate, 4; chloride, 30; phosphate, 10; and lactate, 4.

Bile

If significant amounts of bile are escaping through an external fistula, about 500 ml of the bile should be properly collected daily and introduced through the jejunostomy tube at intervals.

Low Sodium Regimens

Fresh milk as well as milk powder preparations from which the sodium has been removed are available on the market. These can be used as a source of protein when a low sodium intake is desired.

Other Food Mixtures

Other mixtures are available and can be administered. (a) One readily prepared consists of 4 eggs, 480 ml of light cream, 480 ml of homogenized milk, 70 g of Dextrimaltose® and 150 g of a crude protein preparation such as powdered milk or some of those commercially available. Such a mixture will supply approximately 2400 calories per quart. It is best administered by a slow drip over a period of 12 to 16 hours, in order to avoid abdominal cramps and diarrhea.

(b) A formula which has proved satisfactory in the experience of Stewart *et al.*[14] consists of the following: water, 2000 ml; sucrose, 300 g; casein, 200 g; dried yeast, 30 g; trypsin, 5 g; ascorbic acid, 100 mg; halibut liver oil, 1 g; vitamin K, 4 mg; and salt mixture, 10 g. The salt mixture consists of calcium carbonate, 20 g; di-hydrogen sodium phosphate, 16 g; potassium chloride, 28 g; magnesium carbonate, 6 g; sodium carbonate, 6 g; ferric ammonium citrate, 6 g; and sodium chloride, 18 g.

The feeding is prepared by adding the casein slowly to the water with the aid of a mechanical mixer. The volume of the mixture is 2355 ml. It contains 78 per cent water by weight, has a specific gravity of 1.068, a pH of 6.2, and has the following proportions of ingredients: total protein, 196.5 g; total fat, 5.08 g; chloride, 3.9 g; sodium, 4.1 g; calcium 1.1. g; phosphorus, 4.7 g; and potassium, 1.9 g. The caloric value of the mixture may be increased by adding fat in the form of cream or of olive or corn oil, though these may cause diarrhea. The mixture is given each day by gravity drip, preferably continuously over a 12-hour period. If the patient is ambulatory, the administration may be made during the night while he is asleep. If the mixture is instilled intermittently, not more than 3 to 4 ounces should be given every half hour during the day. Giving more than this may distend the jejunal loop and cause symptoms. Occasionally the feedings cause diarrhea, in which case reduction in the amount administered, together with administration of paregoric or anticholinergic drugs, may be helpful. At times the mixture has seemed to be constipating.

REFERENCES

1. Ravdin, I. S., Johnston, C. G., and Morrison, P. J.: Comparison of concentration of glucose in stomach and intestine after intragastric administration. *Proc. Soc. Exper. Biol. & Med.* 30: 955, 1933.
2. Pendergrass, E. P., Ravdin, I. S., Johnston, C. G., and Hodes, P. J.: Studies of the small intestine. II. The effect of foods and various pathologic states on the gastric emptying and the small intestinal pattern. *Radiology* 26: 651, 1936.
3. Shay, H., Gershon-Cohen, J., Fels, S. S., and Monroe, F. L.: Fate of ingested glucose solutions of various concentrations at different levels of the small intestine. *Am. J. Digest. Dis.* 7: 456, 1940.
4. Abbott, W. O., Karr, W. G., and Miller, T. G.: Intubation studies of the human small intestine. VII. Factors concerned in absorption of glucose from the jejunum and ileum. *Am. J. Digest. Dis. and Nut.* 4: 742, 1937.

5. Machella, T. E.: Mechanism of the postgastrectomy dumping syndrome. *Gastroenterology* 14: 237, 1950.
6. Roberts, K. E., Randall, H. T., Farr, H. W., Kidwell, A. P., McNeer, G. P., and Pack, G. T.: Cardiovascular and blood volume alterations resulting from intrajejunal administration of hypertonic solutions to gastrectomized patients: The relationship of these changes to the dumping syndrome. *Ann. Surg.* 140: 631, 1954.
7. Haverback, B. J.: Intraluminal pressure during the dumping syndrome (unpublished data).
8. Boles, T., Jr., and Zollinger, R. M.: Critical evaluation of jejunostomy. *Arch. Surg.* 65: 358, 1952.
9. Goldberg, E. M., Stein, I. F., Jr., and Meyer, K. A.: Administration of fat emulsion by mouth, gastrostomy, and jejunostomy. *J. A. M. A.* 150: 1665, 1952.
10. Fallis, L. S., and Barron, J.: Gastric and jejunal alimentation with fine polyethylene tubes. *Arch. Surg.* 65: 373, 1952.
11. Witzel, O.: I. Zur Technik der Magenfistelangelung. *Zentrabl. Chir.* 18: 601, 1891.
12. Allen, A. W., and Welch, C. E.: Jejunostomy for the relief of malfunctioning gastroenterostomy stoma. *Surgery* 9: 163, 1941.
13. Abbott, W. O., and Rawson, A. J.: A tube for use in the postoperative care of gastroenterostomy patients. *J. A. M. A.* 112: 2414, 1939.
14. Stewart, J. D., Hale, H. W., Jr., and Schaer, S. M.: Management of protein deficiency in surgical patients. Intravenous and intrajejunal injections. *J. A. M. A.* 136: 1017, 1948.

Statistical Man

"Statistical man, by definition, is about average in every respect; real men are likely to deviate markedly from the average in many respects. If it were possible to produce a synthetic statistical men, there is no telling what he would be like. Undoubtedly he would be extraordinary; possibly he would lack susceptibility to disease. Real individuals, on the other hand, have peculiarities in metabolism as well as disease susceptibilities, and it seems reasonable to suppose, as a working hypothesis, that the peculiarities and the susceptibilities are closely related. It also seems reasonable to hope, on the basis of the genetotrophic concept, that many diseases of obscure etiology can be successfully attacked once we are acquainted with their biochemical nature.

The fact that enzyme levels in the blood are characteristically different for different individuals clearly indicates that the body chemistry of each individual is distinctive. While the total metabolism of each of two men of about average height and weight, measured in calories, may be about the same and very close to that of statistical man, the details of the metabolism of each may be highly distinctive. Some specific chemical reactions may be taking place in one individual ten times as fast as they are in another. If this is true, surely this must be the basis for differences in disease susceptibility."

—R. J. Williams, W. D. Brown, and R. W. Shideler. *Proceedings of the National Academy of Sciences* 41: 619, 1955.