CURRENT SURVEY

Metabolic effects of vagotomy and gastric drainage

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IN 1943 Dragstedt & Owens changed the established surgical treatment for chronic duodenal ulceration by re-introducing the operation of vagotomy. It was rapidly recognized that, together with vagotomy, a gastric drainage procedure of some type was essential (Dragstedt & Schafer, 1945). In its early years, vagotomy and drainage rapidly gained in popularity on the basis of simplicity and the low operative mortality of 0-1.7% (Everson *et al.*, 1957; Burge & Pick, 1958; Hamilton *et al.*, 1961; Hendry, 1961), together with a low incidence of post gastric surgery sequelae such as dumping and bilious vomiting. Recently the nutritional hazards of partial-gastrectomy have become recognized (Stammers & Williams, 1963) and it is natural therefore that this aspect of vagotomy and drainage should be closely examined. This paper is principally concerned with reviewing the information we possess about the metabolic and nutritional effects of vagotomy and drainage.

There has been a tendency in the past to consider post-vagotomy nutritional results regardless of the type of gastric drainage used. This is an assumption that, with the knowledge we at present have, is not justified. There are theoretical advantages to performing pyloroplasty as opposed to gastro-jejunostomy; correct sequential mixing of gastric chyme, digestive juices and bile together with appropriate hormonal control by gastrin, secretin and cholecystokinin. In addition the duodenum may be important for the absorption of certain food materials, notably, iron (Wheby, Jones & Crosby, 1964). Gastro-jejunostomy, while being technically possible in all cases, has the disadvantage, in addition to duodenal bypass, of the formation of a blind-loop. Usually this does not cause nutritional problems but occasionally it may lead to malabsorption of fat and vitamin B₁₂, which will be discussed later.

Another possible variant, relevant to nutrition, is that of selective vagotomy. This technique, intro-

duced by Franksson (1948) and Jackson (1948), consists of preservation of all extra-gastric vagal nerve fibres. Its exponents point out that gall bladder innervation is preserved (Harkins *et al.*, 1963) thus preserving normal contractility (Johnson & Boyden, 1952; Rudick & Hutchison, 1964). In addition the blunting and loss of the tips of the jejunal villi seen in dogs after total vagotomy (Ballinger *et al.*, 1965), is prevented.

With these possible technical variations in mind the subject will be considered under the following headings: weight; fat, protein and carbohydrate absorption; haematological status and bone disease.

Weight

Table 1 indicates the percentages of patients who have lost weight after vagotomy either alone or with a particular drainage operation. Considerable variation is seen from one observer to another. In their careful analysis of this problem, Cox *et al.* (1964) and Cox (1965) concluded that weight change after vagotomy and gastro-jejunostomy depended upon the patient's weight at operation relative to the patient's previous 'best weight' as established by the history. Thus subjects who were underweight at operation gained post-operatively, whereas patients who were of normal weight at operation tended to lose weight post-operatively. However, in spite of a post-operative gain in weight they found that there was still an average deficit of between 3.8 and 12.5 kg, from the previous 'best weight'. The implication of this is that although a weight-gain after operation is very satisfactory, patients may still be suffering from some nutritional deficit. The measurement of weight after operation remains an essential index of satisfactory health but it is important not to be lulled into a false sense of security if this should merely remain unchanged or even gain slightly.

From these figures it is not possible to decide whether there is any significant difference between

TABLE 1
Weight loss after vagotomy and drainage

Reference	No. of patients	% losing weight
Total vagotomy alone		
Pollock (1952)	1524	24
Grimson, Rowe & Taylor (1952)	101	46
Williams (1963)*	28	11
Vagotomy plus drainage — unspecified		
Lloyd Davies (1956)	366	9.7
MacKelvie (1957)	473	25
Hamilton <i>et al.</i> (1961)	105	41
Vagotomy and gastro-jejunostomy		
Everson <i>et al.</i> (1957)	178	71.2
Walters & Mobley (1957)	123	14
Cox <i>et al.</i> (1964)	93	28
Tovey (1967)†	58	31
Vagotomy and pyloroplasty or gastroduodenal anastomosis		
Herrington, <i>et al.</i> (1959)	514	10
Hendry (1961)‡	118	15
Tovey (1967)†	72	26

* Fourteen years after operation.

† Total and selective vagotomy combined.

‡ Finney pyloroplasty.

gastro-jejunostomy and pyloroplasty as the gastric drainage procedure when considering post-operative weight loss. There is, nevertheless, a suggestive trend indicating that more patients lose weight after gastro-jejunostomy.

In both the gastro-jejunostomy and pyloroplasty groups, Tovey (1967) compared the effect of selective and total vagotomy. In neither could it be shown that selective vagotomy conferred any significant advantage; a few more patients lost weight after selective than total vagotomy and pyloroplasty, the opposite occurring in the gastro-jejunostomy group.

Fat absorption

One of the most useful and commonly used estimates of malabsorption is the excretion of fat in the faeces (Badenoch, 1960).

Table 2 reviews the changes in faecal fat excretion which have been observed to occur after vagotomy alone and when combined with pyloroplasty or gastro-jejunostomy. It seems clear that vagotomy by itself does not significantly interfere with fat absorption, a fact which is borne out in the experimental animal (Wastell, 1966). It is equally clear that both vagotomy with gastro-jejunostomy and with pyloroplasty does.

The theoretical expectation that fat excretion would be greater after gastric drainage by gastro-jejunostomy (Butler, 1961) than by pyloroplasty, is borne out by Williams & Irvine (1966). They

found that with total vagotomy, gastro-jejunostomy resulted in a significant, if slight, increase in fat excretion over that found with pyloroplasty. Butler (1961) implies a similar finding but Tovey (1967) found no difference between gastro-jejunostomy and pyloroplasty when combined either with total or selective vagotomy. The incidence of steatorrhoea (generally, faecal fat in excess of 7 g/24 hr) varies considerably after vagotomy and gastro-jejunostomy, with the observer from 43% (Cox *et al.*, 1964) to 9% (Tovey, 1967). Similar variation is found after vagotomy and pyloroplasty, Wastell & Ellis (1966) finding steatorrhoea in 50% of their patients while Tovey (1967) found it in only 8%. This variation is difficult to explain particularly as diet has little effect on fat excretion except in persons suffering from some malabsorptive process (Frazer *et al.*, 1949; Frazer, 1961).

TABLE 2
Mean faecal fat excretion after vagotomy and drainage

Reference	No. of patients	Pre-op. (g/24 hr)	Post-op. (g/24 hr)	Increase (g/24 hr)
Vagotomy alone				
Williams (1963)	4	—	2.4	—
Butler & Eastham (1965)	19	—	2.92	—
Vagotomy and gastro-jejunostomy				
Orr (1964)	20	—	6.4	—
Cox <i>et al.</i> (1964)	84	—	7.5	3.6*
Butler & Eastham (1965)	23	2.14	5.70	3.56
Williams & Irvine (1966)†	23	1.87	4.50	2.69
Tovey (1967)†	25	—	3.5	0.4*
Vagotomy and pyloroplasty				
Kiekens & Geertruyden (1963)	6	3.2	11.3	8.1
Orr (1964)	20	—	5.2	—
Kraft <i>et al.</i> (1965)‡	20	—	6.49	—
Williams & Irvine (1966)†	42	1.88	4.35	2.47
Wastell & Ellis (1966)	20	2.4	6.5	4.1
Tovey (1967)†	86	—	3.1	0*

* Increase over control group.

† Includes both total and selective vagotomy.

‡ Finney pyloroplasty.

Neither Williams & Irvine (1966), Tovey (1967) nor Kraft *et al.* (1965) could detect any significant difference between the fat excretion after total as compared with that after selective vagotomy and drainage.

The mechanism whereby this malabsorption occurs is interesting; in dogs various types of vagotomy do not result in a significant increase in

faecal fat excretion but when one of these is combined with a pyloroplasty a large and significant rise occurs. Further, when pyloroplasty is performed alone, without vagotomy, there is again a similar rise in faecal fat excretion suggesting that where the antral-pyloric-duodenal mechanism is interfered with a defect of fat digestion results (Wastell, 1966). It is likely that there is also interference with this mechanism in the case of gastro-jejunosomy, together with poor mixing of the food with bile (Pessoa, Kim and Ivy, 1953; Butler, 1961). Another factor may be operating as well. Drasar, Hill & Shiner (1966) have demonstrated that several strains of the *Bacteroides* group of bacteria are found in the human jejunum and have the ability to deconjugate bile salts *in vitro*. Unconjugated bile salts are probably less efficient in promoting the formation of a micellar solution (Mattson *et al.*, 1952; Hoffman & Borgstrom, 1964; Hoffman, 1965) and, in addition, if present in sufficient concentration, may be toxic to small-bowel mucosal cells (Dawson, Isselbacher & Bell, 1960; Tabaqchali & Booth, 1966). Some support to this, as an hypothesis for fat malabsorption, is lent by the fact that occasionally the steatorrhoea occurring in association with vagotomy and gastro-jejunosomy is improved by giving antibiotics.

If pyloroplasty by itself results in malabsorption of fat the question arises as to what type of pyloroplasty should be performed. Is there conflict in the fact that a 'large' pyloroplasty will serve to drain the antrum well but will produce a significant defect in fat absorption and vice versa? It has been found, in dogs (Wastell, 1967, unpublished observations), that the area of the gastric outflow tract resulting from pyloroplasty bears a significant positive correlation to the increase in faecal fat excretion up to the point at which that area equals the cross-sectional area of the duodenum. Beyond this the results become variable but the average increase in faecal fat is no greater. This indicates that the most important consideration is drainage of the antrum, and larger pyloroplasties, for example the 'Finney', may be used without extra nutritional disadvantage.

Vagotomy and drainage results, therefore, in an increase in faecal fat excretion. This may be an index of malabsorption of other food materials and although by itself may not cause embarrassment by caloric loss, carries with it the risk of reduced absorption of fat-soluble vitamins, particularly vitamin D, calcium and possibly magnesium (Booth *et al.*, 1963).

Protein absorption

There is little information relating to the absorption of protein after vagotomy and drainage.

Baldwin *et al.* (1964) found a significant rise in faecal nitrogen in dogs after vagotomy alone and vagotomy with pyloroplasty; a slight rise after selective vagotomy and pyloroplasty and no rise at all after pyloroplasty alone. However, also using dogs, Tucker, Barnet & Goodrich (1963) found only delayed absorption of [¹³¹I] serum albumin after total vagotomy and this was returned to normal by pyloroplasty. No alteration in the timing of absorption was found if the vagotomy was selective. Golding *et al.* (1965), using a similar technique, found no significant change in absorption after total vagotomy with, or without, pyloroplasty.

In human subjects with chronic duodenal ulcer, neither Cox (1965), after vagotomy and gastro-enterostomy, nor Kiekens & Geertruyden (1963) and Kraft *et al.* (1965), after vagotomy and pyloroplasty, found significantly raised mean faecal nitrogen levels in seventy-six, six and twenty patients, respectively. The latter group of authors also compared the faecal nitrogen levels after selective, as opposed to total, vagotomy and pyloroplasty and found that no difference existed.

Taking both animal and human experience it would seem therefore that no great defect in protein digestion and absorption has yet been described. However, it is well to point out that techniques so far used have been rather crude and non-specific, and further work may result in different conclusions being reached.

Carbohydrate

There is no evidence of any impairment of either carbohydrate digestion or absorption after these operations. When studying the feasibility of duodenal feeding after vagotomy Cox (1962) demonstrated slight delay in glucose absorption 18 hr after operation which had returned to normal 6 days later. Williams & Irvine (1966) found a 'flat lactose curve' in 9% of patients after total and 12% of patients after selective vagotomy and pyloroplasty but, as they point out, their findings are probably not significantly different from a control population.

Haematological status

Haemoglobin

A reduction in haemoglobin levels has been reported by Burge & Pick (1958) 8 years after vagotomy and gastro-jejunosomy and Feggetter & Pringle (1963) 10-14 years after the same procedure. However, these findings are of doubtful significance in relation to vagotomy since the pre-operative levels were not mentioned. Similar findings were recorded by Cox *et al.* (1964) up to 4 years after vagotomy and gastro-jejunosomy. It

was found in this latter study that women were much more liable to develop anaemia than men, but that those subjects who were noted to be anaemic before operation tended to become anaemic after operation as well. Although these data suggest that in the long term a few patients may become anaemic by virtue of the vagotomy and drainage, a significant fall in haemoglobin could not be demonstrated. No data at all are available, in a long-term follow-up, of patients after vagotomy and pyloroplasty.

Iron

Serum iron tends to fall after vagotomy and gastro-jejunostomy both in men and women. This is, perhaps, not surprising for several reasons. Gastric acid is thought to facilitate the absorption of dietary iron (Goldberg, Lochhead & Daag, 1963; Jacobs *et al.*, 1966) and in addition the duodenum may be important for the absorption of iron to take place (Wheby *et al.*, 1964). Also, as well as the above theoretical reasons for reduced absorption, Hoffbrand *et al.* (1967) found that 40% of unselected patients had a dietary intake of less than 10 mg iron/day, which he considered to be inadequate.

The fact that iron is probably absorbed from the duodenum constitutes a theoretical advantage, in this respect at least, in favour of pyloroplasty over gastro-jejunostomy. But unfortunately serum iron levels have not yet been reported in patients several years after vagotomy and pyloroplasty.

Vitamin B₁₂

The mean serum vitamin B₁₂ levels in eighty-three patients (sixty-six males and seventeen females) 4 years after vagotomy and gastro-jejunostomy was 310 pg/ml (Cox *et al.*, 1964), a figure well within the normal range. However, even though the results when examined for progressive change with time from operation showed no diminution, the B₁₂ absorption, as judged by the Schilling test, was depressed in 19% of males and 13% of females. This finding is in accord with the observations of Muyschondt & Schwartz (1964), that diminished B₁₂ absorption, sustained for 3 months, occurred after vagotomy and pyloroplasty in dogs, an abnormality corrected by the addition of intrinsic factor.

Even though there is this suggestive evidence of impaired B₁₂ absorption, megaloblastic anaemia due to vagotomy and drainage has not yet been reported.

Folate

No values for serum folate after vagotomy and drainage have been reported. If folate deficiency

occurs after this operation it is likely to be rare and may well occur principally on the basis of an inadequate intake (Neale & Hoffbrand, 1967).

Bone disease

Osteomalacia

This has not, so far, been reported following a vagotomy and drainage operation although it has occurred following gastro-jejunostomy alone (Nordin & Frazer, 1956). It remains, however, in view of the other evidence of malabsorption, a possibility in patients who have been operated on many years previously. The diagnosis depends on the finding of a low serum calcium, low serum phosphate, raised serum alkaline phosphatase, osteoid seams in bone greater than 15 μ wide and a response to vitamin D (Morgan *et al.*, 1965a). The significance of a raised serum alkaline phosphatase was challenged by these workers on the grounds of variability; however, Thompson *et al.* (1966), correlating this quantity with calcium infusion tests, bone biopsy and plasma vitamin-D-like activity, reaffirmed its usefulness as a screening procedure. Post-gastrectomy osteomalacia is due to lack of vitamin D, in turn due to low dietary intake (Morgan *et al.*, 1965b) combined with malabsorption (Thompson, Lewis & Booth, 1966).

It is likely that as time goes by, providing a high index of awareness is maintained, some cases of osteomalacia will be found after vagotomy and drainage. If this supposition is correct, early treatment with small doses of vitamin D and calcium should prove effective.

Osteoporosis

As with osteomalacia this condition has not been described following vagotomy and drainage. The diagnosis depends on the radiological finding of loss of mineralization of bones, often with collapse or fracture but without Looser's zones. It is entirely possible for osteoporosis and osteomalacia to co-exist.

Conclusion

It is now becoming apparent that vagotomy and drainage is followed by some derangement of digestion and absorption. The full significance of this derangement will only be adequately assessed by further long-term follow-up studies. Experience with gastrectomy indicates that a post-operative time interval of 10-15 years may be necessary before some of the deficiency states become manifest. It is very important, therefore, for clinicians to be aware of the possible problems.

It is probable that vagotomy and pyloroplasty results in a smaller metabolic derangement than

vagotomy and gastro-jejunostomy, and that both are better in this respect than any form of gastrectomy (Boley *et al.*, 1965). It is more important to ensure an adequate pyloroplasty with adequate drainage of the gastric antrum than to limit the size of the pyloroplasty in an attempt to limit the interference with nutrition. In the material so far published no difference has been found between total vagotomy and selective vagotomy in respect to digestion and absorption.

It has been suggested that however severe is the metabolic defect which follows surgery for duodenal ulcer, deficiency states are rare in the face of adequate dietary intake. This, perhaps, in a practical sense, is the most important aspect of this subject but one about which little information exists.

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