Original article

Optimal gastric pouch reconstruction post-gastrectomy

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Abstract

Background. Gastric pouches have the potential to improve nutrition following total gastrectomy, compared with standard reconstruction. However, a consensus view of clinical benefit is not available, at least partly due to a lack of standardization of pouch design or size. This study was undertaken to identify optimal conditions for pouch design.

Methods. A mathematical model was established and a porcine model constructed to evaluate the pressure/volume dynamics of the pouch. A “J” pouch was constructed at anastomotic lengths of 5, 10, 15, and 20 cm. Each pouch was distended with saline and the pressure/volume relationship established.

Results. Mathematically, increasing the anastomotic length of the pouch to 15 cm increases the volume significantly; thereafter, there is minimal benefit of increasing the pouch length further. For smaller pouches (5 and 10 cm) a 350- to 400-ml volume (approximate meal volume in the elderly) is never achieved until higher pressures (45 cmH₂O) are applied. However, in the larger pouches (15 and 20 cm) a 350- to 400-ml volume is readily achieved at basal pressures of 15 cmH₂O.

Conclusion. Smaller pouches never achieve adequate volumes at basal pressures; accordingly, it is unlikely that they will lead to any clinical benefit. Further in-vivo studies should therefore be based upon 15-cm pouch designs.

Key words Gastric cancer · Total gastrectomy · Gastric pouch · Reconstruction · Mathematical modeling

Introduction

Following total gastrectomy, loss of the gastric reservoir and normal duodenal transit results in a group of symp-

toms characterized by symptoms of early satiety, epigastric discomfort, nausea, and vomiting [1]. Reduction in calorie intake due to loss of stomach volume appears to be the single most important determinant of weight loss post-gastrectomy [2, 3].

To prevent the consequences of loss of gastric reservoir, over 50 different reconstruction procedures have been reported since the first successful total gastrectomy was described by Schlatter in 1887 [4–6]. Roux, in 1907, described a reconstruction technique, which is currently standard practice at many centers, to establish intestinal continuity following resection of the stomach [4]. However, this does little to improve the reservoir function following surgery. In an attempt to overcome this problem, the first pouch reconstruction was described by Hoffmann in 1922, and was further developed by Hunt in 1952 [7], Rodino in 1952 [8], and Lawrence in 1962 [9]. A combination of the latter three designs, resulting in a “J”-shaped jejunal pouch, has been the most commonly constructed form of gastric pouch. Identifying the optimal reconstruction from the large number of possible techniques continues to be controversial.

A number of studies have suggested that construction of a pouch may improve eating capacity and therefore reduce weight loss following gastrectomy; however, there has been little attempt at standardization of pouch design [10–14]. Furthermore, individual studies of pouch design are generally limited by small patient numbers, short follow-up, and variable outcome measures [10, 15–17]. Due to this variability, a metaanalysis of studies cannot be conducted and, hence, a definitive statement of the benefit of pouch reconstruction cannot be made.

The aims of this study were to construct a mathematical model to quantify gastric pouch volume and justify a range of gastric pouch dimensions to be tested in an in vitro model.

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Fig. 1. Mathematical model based on equating the “J” pouch to a hemisphere plus a cylinder. Volume of pouch = $(2/3) \pi r^3 + \pi r^2 l$, where r is the constant diameter for the jejunum and l is a variable stapled anastomotic length for the pouch

Methods

Mathematical model

A mathematical model, based on equating the “J” pouch to a hemisphere plus a cylinder was developed. From this we ascertained a formula to evaluate the volume of a pouch given a constant diameter for the jejunum (r) and a variable stapled anastomotic length (l) for the pouch (Fig. 1). In this way we looked at the increase in pouch volume relative to increasing the stapled length of the anastomosis, and we compared this to the volume of the native length of jejunum required to create the pouch.

The equations used were:

$$\text{Volume of pouch} = (2/3) \pi r^3 + \pi r^2 l$$

$$\text{Volume of native length of jejunum} = \pi (r/2)^2 (2l + \pi r)$$

In vitro assessment of pouches

A “J” pouch was constructed, at anastomotic lengths of 5, 10, 15, and 20 cm, with porcine intestine, using Ethicon Proximate linear cutters (TLC 55 and TCT 75; Ethicon-Endo-Surgery, Edinburgh, UK) for the pouch reconstruction and a Proximate curved intraluminal stapler (29 mm) for the esophagojejunal anastomosis.

Using a specially designed platform (Fig. 2), the pouches were submerged in water (density 1000 kg/m^3) prior to distension in order to minimize distortion from gravity. The pouches were suspended from a length of

Fig. 2. Platform used for in vitro assessment of constructed pouches

nondistensible rubber tubing attached to a weighing scale.

Three different lengths of rubber tubing were used to generate distending pressures of 15, 30, and 45 cmH₂O. The pouches were distended with a continuous flow of 5% saline solution (50 g NaCl in 1000 ml H₂O — density 1035 kg/m^3) to account for potential anastomotic leaks.

The weight change of the nondistended to distended pouch at each pressure was measured and the change in volume calculated using the following formula:

$$\Delta V = \Delta W / g(\rho_s - \rho_w)$$

Where ΔV = volume change (m^3)

g = acceleration due to gravity (m/s^2)

ρ_s = density of 5% saline solution (kg/m^3)

ρ_w = density of water (kg/m^3)

ΔW = change in measured weight (N)

Pouches were constructed in duplicate and measurements performed in triplicate.

Fig. 3. Mathematically generated pouch volume ratio, pouch: native jejunum

Results

Mathematical model

When the diameter of the jejunum remains constant at 3.5 cm (average diameter of human jejunum), with increasing anastomotic length there is a linear increase in pouch volume. When comparing the volume of the “J” pouch to that of the native length of the jejunum required to create the pouch (volume ratio, pouch: native jejunum), an increase in volume is achieved with a pouch compared to the native jejunum (Fig. 3). This ratio increases with increasing anastomotic length, but begins to plateau at 15 cm, where the volume ratio between pouch and native jejunum is 1.70 (volume of pouch = 668 cm³; volume of native jejunum = 394 cm³).

Based on the mathematical model, the following in vitro pouch anastomotic lengths were chosen for further evaluation: 5, 10, 15, and 20 cm.

In vitro assessment of pouches

The 5-, 10-, and 15-cm pouches demonstrated a small increase in volume when distending pressures were increased from 15 to 30 cmH₂O. However, when these pressures were increased further from 30 to 45 cmH₂O a proportionally greater increase in volume was noted, in comparison to the initial pressure increase from 15 to 30 cmH₂O. A direct correlation between pressure and volume increase was noted with the 20-cm pouches (Fig. 4).

At 15 cmH₂O (basal pressure), volumes of 110, 232, 336, and 380 ml are achieved with 5-, 10-, 15-, and 20-cm pouch sizes, respectively.

Fig. 4. Pressure/volume analysis for constructed pouches (5, 10, 15, and 20 cm). Pouches were constructed in duplicate and measurements performed in triplicate. Data values are presented as means $\pm$ SD

At 30 cmH₂O (intermediate pressure), volumes of 144, 258, 374, and 624 ml are achieved with 5-, 10-, 15-, and 20-cm pouch sizes, respectively.

At 45 cmH₂O (high distending pressure), volumes of 361, 621, 775, and 898 ml are achieved with 5-, 10-, 15-, and 20-cm pouch sizes, respectively.

Discussion

Mathematical model

Our mathematical model highlights the increase in volume that can be obtained when using a length of bowel similar in size, but refashioning it into a “J” pouch.

We have shown that increasing the anastomotic length of the pouch up to 15 cm increases the volume significantly; thereafter, the same benefit of increasing length does not accrue. This is demonstrated by the plateau seen on the volume ratio, pouch: native jejunum graph (Fig. 3).

Hence, there appears to be reduced mathematical benefit from increasing the anastomotic length beyond 15 cm.

We accept the limitations associated with this simplified mathematical model. In patients, “J” pouches may not always equate to a hemisphere plus a cylinder. However, we felt that this was the most applicable geometric model to use to generate a formula for pouch volumes.

In vitro assessment of pouches

Liedman et al. [18] demonstrated that intragastric/pouch pressures approaching 15 cmH₂O were tolerated by patients without experiencing symptoms of satiety;

whereas higher pressures approaching 45 cmH₂O were poorly tolerated by patients, resulting in epigastric pain, nausea, and vomiting.

An average meal size in elderly patients equates to 350–400 ml, according to data gathered from our unit. The smaller pouches (5 and 10 cm) were unable to achieve such volumes at basal and intermediate pressures, i.e., pressures that would be tolerated by patients without experiencing satiety. With the smaller pouches, in excess of 350 ml was only attainable with distending pressures of 45 cmH₂O, at which stage patients would experience troublesome symptoms such as epigastric pain, nausea, and vomiting, in accordance with work carried out by Liedman et al. [18]. However, the larger pouches (15 and 20 cm) achieved the desired volume at basal and intermediate pressures which could be tolerated by patients without adverse side effects.

We accept the limitations associated with the use of nonviable bowel within our in vitro assessment and its potentially differing distensible properties when compared to vascularized and innervated human jejunum. We did, however, use freshly harvested porcine intestine during our pouch construction and testing.

Based on our study, there appears to be little benefit of smaller pouches (5 and 10 cm) in further in vivo reconstructions, as they are unable to achieve ideal meal volumes at pressures that do not evoke troublesome symptoms in patients. Further in vivo testing should involve larger pouches, i.e., greater than 10 cm, taking into consideration the reduced mathematical benefit gained from exceeding an anastomotic length of 15 cm. Hence, the 15-cm pouches achieve the appropriate pressure/volume dynamics and can be constructed using two 7.5-mm staples.

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