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Efficacy of Gastric Blood Supply Redistribution by Transarterial Embolization: Preoperative Procedure to Prevent Postoperative Anastomotic Leaks Following Esophagoplasty for Esophageal Carcinoma

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Abstract

Purpose: The aim of this study was to evaluate the effect of preoperative redistribution of gastric blood supply on the prevention of anastomotic leakage following surgical reconstruction of the esophagus.

Methods: In 37 patients with esophageal carcinoma, transarterial embolization (TAE) of the left gastric, right gastric, and splenic arteries was preoperatively performed with coils so that gastric blood supply was dependent only on the right gastroepiploic artery.

Results: In 34 of 37 patients, preoperative redistribution was successfully performed. The gastric tissue blood flow (TBF) of a gastric tube was higher than in 12 nonredistributed patients. Reduction in the gastric TBF during preparation of a gastric tube was 27.5% in successful patients, in contrast to 68.9% in 12 nonredistributed patients ($p < 0.005$).

Conclusion: Preoperative redistribution by TAE reduced the drop in gastric TBF during preparation of a gastric tube and helped prevent postoperative anastomotic leakage in esophageal reconstruction.

Key words: Esophagus, neoplasm—Angiography, preoperative—Arteries, therapeutic blockade—Surgery, complication

Anastomotic leakage after esophagoplasty using a gastric tube following esophagectomy for esophageal carcinoma is one of the most common and serious complications, with a reported incidence of 6.3%–26.7% [1–4]. In patients with anastomotic leakage, Patil et al. [3] and Lee et al. [4] have reported a high mortality rate of 64.1% and 22.3%, respectively.

One of the major causes of this complication is a sudden decrease in gastric blood supply during surgical preparation of the gastric tube, secondary to ligation of the left gastric artery (LGA), right gastric artery (RGA), and short gastric arteries, leaving the right gastroepiploic artery (RGEA) as the sole supply of the gastric tube. There have been no reports describing effective measures to prevent this complication.

In order to reduce the risk of postoperative anastomotic leakage, we attempted to make the gastric blood supply dependent only on the RGEA by percutaneous transarterial embolization (TAE) of the other gastric arteries about 2 weeks prior to the surgery. By the time of surgery this artery was expected to provide adequate blood supply for the entire stomach.

We report the results of this preoperative intervention and the assessment of gastric tissue blood flow (TBF) at surgery compared with a nonembolized control group.

Materials and Methods

Patients

Over the 3-year period from January 1993 to December 1995, preoperative redistribution (POR) was attempted in 37 of 49 consecutive patients with esophageal carcinoma who were judged to be candidates for resection. All patients received a full explanation of the risks and possible benefits of the new procedure, and written

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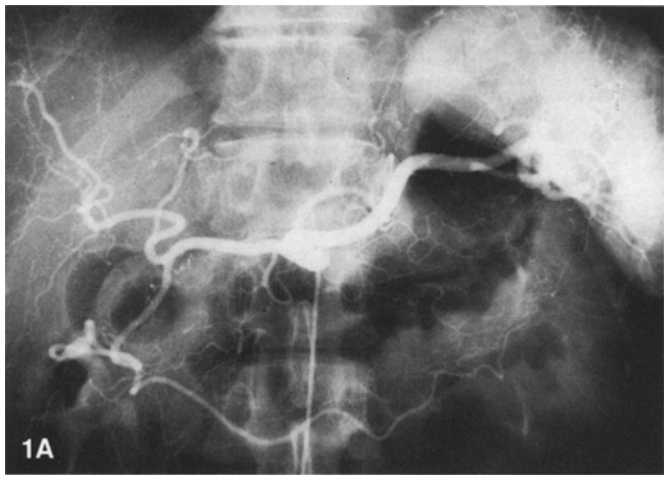

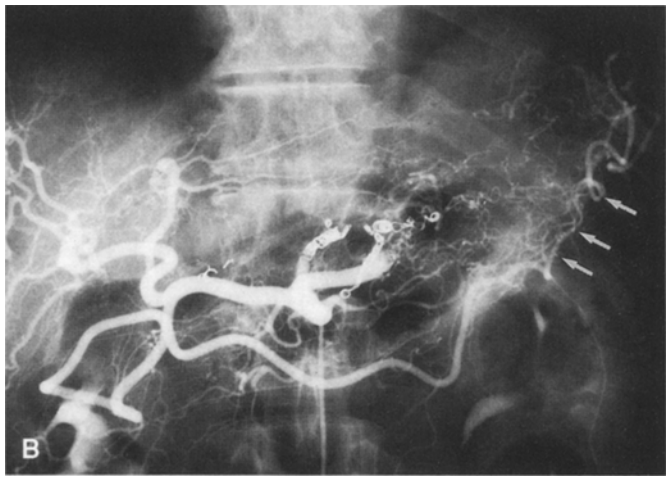

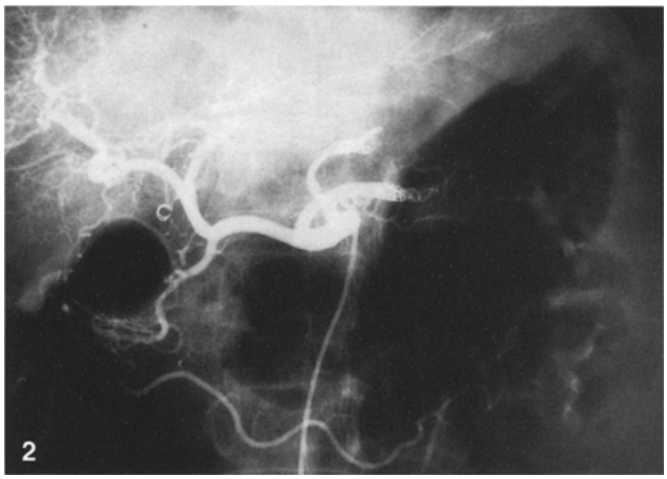

Fig. 1. **A** Celiac arteriogram before preoperative redistribution. **B** After embolization of the gastric supply, including the left inferior phrenic artery, the only remaining right gastroepiploic artery now fills the left gastroepiploic artery (arrows).

Fig. 2. In this patient the left gastroepiploic artery does not fill from the right gastroepiploic artery following our embolization of other gastric supply.

informed consent was obtained. In the same period the other 12 patients who did not undergo POR (due to limited angiographic capacity and scheduling conflicts) were used as controls. The 37 patients consisted of 28 males and 9 females, average age 59.0 years (range 44–75 years), the controls were 11 males and 1 female, average age 61.0 years (range 48–75 years).

Preoperative Redistribution by TAE

POR was performed by TAE of the LGA, RGA, and splenic artery (SA) [5]. In general, TAE was performed with 0.035-inch stainless steel coils and 0.018-inch microcoils (both devices; Cook, Bloomington, IN, USA) placed within the artery through a standard 5 Fr catheter and a 3 Fr coaxial microcatheter (Tracker; Target Therapeutics, Fremont, CA, USA), respectively. However, in two patients, a 1 : 2 mixture of n-butyl-2-cyanoacrylate (NBCA) and iodized oil contrast medium (Lipiodol; Andre Guerbet, Aulnay-sous-Bois, France) was used to embolize the RGA because the antegrade insertion of the microcatheter into this artery was not deep enough to safely use microcoils. This mixture was slowly injected into the main trunk of the RGA about 5 mm distal to its origin at the parent artery. The reason for using a mixture of NBCA and iodized oil contrast medium was not only to permit fluoroscopic visualization but also to regulate the setting time [6].

LGA and RGA embolization was performed from the main trunk to the first branch point. SA embolization was performed near the midportion of the main trunk. For RGA embolization an antegrade approach was sometimes very difficult. In that case, we attempted retrograde embolization of the RGA via the arcade on the side of the lesser curvature of the stomach with a microcatheter, using a 5 Fr catheter inserted into the LGA as a guide. This maneuver was successfully performed on most attempts. When gastric blood supply from arteries other than the RGEA was observed after embolization, these arteries were also embolized in order to achieve the highest possible development of RGEA collateral supply. Once the LGA, RGA, and SA were occluded, the embolization procedure was considered successful.

Conventional film celiac arteriography was routinely performed before and after embolization. Based on post-embolization angiographic findings, the patients were divided into two groups: those with opacification of the left gastroepiploic artery (LGEA) from the right GEA (Fig. 1B) and those without (Fig. 2).

Operative Procedure

The anterior fornix wall of the stomach is the anastomotic site for the esophagogastrostomy and has the most precarious tissue perfusion after preparation of a gastric tube [7]. Therefore, TBF was measured at this location with a laser flow meter (model ALF 2100; Advance, Tokyo, Japan) before and after the preparation of a gastric tube in all patients including the 12 controls. Data were computed with a MacLab recorder/analyzer (AD Instruments Pty.

Ltd., New South Wales, Australia). A gastric tube was prepared with ligation of the left, right, and short gastric arteries, and esophageal reconstruction was performed by means of a cervical or intrathoracic anastomosis, as appropriate.

The rate of decrease in TBF during the preparation of a gastric tube for the redistributed patients and the controls was compared, as was that for the two post-redistribution groups. Differences were analyzed using the Student's t test and the χ^2 test, with a value of $p < 0.05$ considered statistically significant.

Results

Transarterial Embolization

Embolization of the LGA, RGA, and SA was successfully performed in 34 (92%) of 37 patients. In 2 of the 3 patients with unsuccessful POR, the RGA alone could not be embolized because of anatomical difficulty. In the third patient, we were forced to abandon the entire procedure because of severe arteriosclerosis.

In 32 of the 34 patients with successful POR, embolization was performed with 0.035-inch steel coils and/or 0.018-inch microcoils. In the remaining two patients, embolization of the RGA was performed with a mixture of NBCA and Lipiodol. Arteries embolized in addition included an accessory left gastric artery in four patients and the inferior phrenic artery in two patients (Fig. 1B). The accessory left gastric artery arising from the left hepatic artery was occluded at the main trunk and embolized with 0.018-inch microcoils in all four patients. The inferior phrenic artery was embolized with 0.018-inch microcoils in two patients.

Surgery

Surgery for esophageal carcinoma with additional splenectomy was performed from 4 to 74 days after POR (average, 13.8 days). During surgery, gastric TBF was measured in 30 of 34 patients undergoing successful POR, in 2 patients with unsuccessful embolization of only the RGA, and in the 12 controls. In the remaining 4 of the 36 patients who underwent preoperative TAE, intraoperative TBF was not measured for various reasons.

In 27 of 30 patients with successful POR surgery was performed within 18 days (range 4–18 days) after redistribution. In the remaining three patients, surgery was performed from 38 to 74 days after redistribution because of adjuvant chemotherapy. In two patients with unsuccessful embolization of only the RGA, surgery was performed 6 and 14 days, respectively, after redistribution.

According to post-redistribution angiography, the LGEA filled from the right in 28 patients (Fig. 1B), but not in the remaining two patients (Fig. 2).

Gastric TBF measurements are summarized in Tables 1 and 2. Before preparation, TBF in the controls was about twice as high as that in the POR patients (mean ± SD 20.4 ± 6.8 vs 11.9 ± 4.4 ml/min/100 g). However, after preparation, gastric TBF in the POR patients was significantly higher than that in the controls (mean ± SD 8.7 ± 4.0 vs 6.4 ± 2.7 ml/min/100 g; $p = 0.086$ by t test).

Table 1. Average gastric tissue blood flow and degree of reduction during preparation

	n	Tissue blood flow [mean ± SD (ml/min/100 g)]			Reduction (%)		
		Before preparation	After preparation				
Preoperative redistribution	30	11.9 ± 4.4	8.7 ± 4.0	]	27.5		]
RGEA filling (+)[a]	28	11.5 ± 4.8	8.9 ± 4.3	*	22.6	]**	**
RGEA filling (−)	2	17.5 ± 0.7	5.0 ± 0.0		71.4		
Failed redistribution[b]	2	9.6 ± 2.1	3.4 ± 0.8	]	63.2		
Controls	12	20.4 ± 6.8	6.4 ± 2.7		68.9		]

*$p = 0.086$; **$p < 0.005$ (t-test)
[a] RGEA filling (+): right gastroepiploic artery fills the left gastroepiploic artery in post-redistribution angiography.
[b] Failed redistribution: patients with unsuccessful embolization of only the right gastric artery.

Table 2. Gastric tissue blood flow after preparation of the gastric tube

	n	Tissue blood flow (ml/min/100 g)		
		< 5.0	5.0–10.0	> 10.1
Preoperative redistribution	30	1	19	10
RGEA filling (+)	28	1	17	10
RGEA filling (−)	2	0	2	0
Failed redistribution	2	2	0	0
Controls	12	4	7	1

The degree of TBF reduction during preparation of a gastric tube was 27.5% on average in patients with successful POR and 68.9% in the controls, a significant difference ($p < 0.005$). The 28 patients with RGEA to LGEA filling on post-redistribution angiography had a 22.6% reduction; those without had a 71.4% reduction in TBF, again a significant difference ($p < 0.005$). In two patients with unsuccessful embolization of only the RGA, TBF after preparation of a gastric tube was 2.8 and 3.9 ml/min/100 g with a reduction in TBF of 74.5% and 51.9%, respectively, during preparation of a gastric tube (Table 1).

TBF of less than 5.0 ml/min/100 g (critical point for leakage) after the preparation of a gastric tube was observed in 1 (3.3%) of 30 patients with successful POR, and in 4 (33.3%) of 12 controls (Table 2).

Complications

One patient developed necrotizing cholecystitis and hepatic micronecrosis because retrograde flow of NBCA led to partial occlusion of the cystic and hepatic arteries while the RGA was embolized. Clinical improvement was observed after 1 week, and a week later, another surgical procedure for esophageal carcinoma was performed.

Minor complications were a small amount of extravasation in each patient at the embolized sites of the LGA, RGA, and accessory left gastric artery, without clinical symptoms.

Mild abdominal pain was observed in 29 patients for a few days after redistribution, but no splenic infarction of sufficient degree to pose a clinical problem was identified.

During surgery, partial splenic infarction, estimated to be less than 20%, was recognized in six patients with POR. However, no major infarction was observed. There were no grossly visible ischemic changes in the stomach attributable to POR. Moreover, the color of the gastric tubes after preparation in patients with POR was far better than that in controls.

A minor anastomotic leak was observed in 1 of 34 patients with successful POR. However, this patient was discharged from the hospital within a few weeks, following only conservative management.

Discussion

The principal causes of anastomotic leakage in esophageal reconstruction with a gastric tube are improper surgical technique and the sudden decrease in gastric TBF following ligation of the gastric arteries, other than the RGEA, and the fact that the TBF in the gastric tube itself is small in absolute terms.

Miyoshi [8] measured partial tissue oxygen pressure in the gastric tube and reported that it fell significantly and remained unstable for 5 postoperative days before recovering and stabilizing at the value measured immediately after surgery. Urschel [9] found that oxygen requirements for successful anastomotic healing exceeded those of simple maintenance of gastric viability after mobilization. Furthermore, Urschel [10] found that, in rats, gastric TBF decreased to 27% immediately after ligation of the LGA, then recovered to 60% 1 week later, and to 81% 2 weeks later (the "delay" phenomenon). From this point of view, if redistribution of the gastric blood supply from only the RGEA is performed by TAE 1 week or so before surgery, the enlarged RGEA will prevent the gastric TBF from suddenly decreasing during surgery. And sufficient TBF in the gastric tube will minimize anastomotic leakage following esophageal reconstruction.

The gastric TBF of patients with POR was reduced compared with that of controls before the preparation of a gastric tube. However, after preparation, it fell much less than that of controls. Therefore we demonstrated that POR maintained adequate TBF in the gastric tube both before and after surgery.

In this study, a minor anastomotic leak was observed in only one patient (3.3%) after POR. The fact that this complication was not observed in any of the controls is most likely a function of the smaller number of patients (12 in the control group vs 30 in the POR group). On the other hand, during a 4-year period (1989–1992), anastomotic leakage was observed in 12 of 73 patients (16.3%) undergoing the same surgical procedure by the same surgeons at our institution. There was also a significant difference between the current and previous patients ($p < 0.05$) using the χ^2 test. The rate of occurrence in our study is better than that in the recent literature [1–4], even though our primary experience includes only 34 patients. According to surgical research at our facility up to 1992, anastomotic leak took place frequently in those patients in whom TBF of the gastric tube dropped below 5.0 ml/min/100 g immediately after preparation, with a rate as high as 75% [5]. In this current study, it was found that such a poor gastric TBF occurred in only 3.3% (1 of 30) of patients in the POR group and 33% (4 of 12) of controls (Table 2). These facts indicate that POR will make it possible to effectively prevent anastomotic leakage following esophageal reconstruction.

In those two patients where post-redistribution angiography did not show filling of the LGEA from the right, TBF in the gastric tube did not differ from controls. In these patients, gastric TBF before preparation was very high, even though the post-redistribution angiogram did not show the anastomosis from the RGEA to LGEA. This may be due to the fact that the LGEA was deriving its in-flow from arteries other than the RGEA, such as the left inferior phrenic artery. It is known that there is no direct anastomosis between the two gastroepiploic arteries in about 10% of the population [11]. In such patients, it may be assumed that postoperative TBF in the gastric tube may have fallen even further without POR, or that this procedure would have been ineffective. This uncertainty will only be resolved with additional experience.

For POR of gastric blood flow by TAE, embolization of all but the RGEA is essential. Failure to embolize the RGA in our patients was associated with a significant decrease in gastric TBF during preparation of a gastric tube. This finding implies that the gastric blood supply from the RGA had actually increased by the time of surgery.

Embolization of the RGA is difficult in most patients. In our opinion the most efficient and safest route for performing the procedure is via the LGA using a microcatheter. Irrespective of various anatomical variations in the RGA, this method is able to roughly halve the time required for the embolization, when it can be successfully carried out. The principal reason that this method cannot be used is that the arcade is too small in diameter or too tortuous to permit passage of a microcatheter.

During surgery, no major infarction in the spleen was observed in the patients with POR. Anderson et al. [12] reported in experiments with dogs that after occlusion of the SA with steel coils, the peripheral arterial branches in the spleen remain patent and function as channels for collateral circulation. In POR, the embolization site in the SA was the midportion of the common trunk. Accordingly, it could be considered that collateral circulation prevented severe splenic infarction and necrosis. We believe that SA embolization in this procedure is safe.

In conclusion, POR with TAE significantly reduced the loss of TBF in the gastric tube during preparation. Moreover, it was effective in maintaining adequate TBF. Based on these findings, this new procedure is a promising therapeutic

method for preventing postoperative anastomotic leakage in esophageal reconstruction.

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