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The subpyloric space: an important surgical and radiologic feature in pseudomyxoma peritonei

P. H. Sugarbaker

The Washington Cancer Institute, Washington, D.C., USA

Aims: If mucinous appendiceal tumours widely distributed throughout the peritoneal space are completely removed by peritonectomy procedures, quality of life and survival benefits result with an acceptable morbidity and mortality. In some patients mucinous tumour that surrounds the stomach is an important consideration in accomplishing a complete cytoreduction.
Methods: Mucinous tumour that enters the lesser sac through the foramen of Winslow will accumulate by gravity in the subpyloric space. This is a cul-de-sac beneath the pylorus. For complete cytoreduction mucinous tumour accumulation in the subpyloric space must be cleared.
Results: If there is tumour accumulation in the subpyloric space and the left gastric artery can be preserved by peritonectomy, one can achieve a complete cytoreduction without gastrectomy. In a majority of patients, resection of mucinous tumour from the subpyloric space requires total gastrectomy for complete cytoreduction.
Conclusion: Knowledge of mucinous tumour distribution and anatomy of the subpyloric space will facilitate complete cytoreduction in selected patients with pseudomyxoma peritonei syndrome.

Key words: cytoreductive surgery; peritoneal carcinomatosis; pseudomyxoma peritonei; appendiceal cancer; intraperitoneal chemotherapy; 5-fluorouracil; mitomycin C.

INTRODUCTION

Gastrointestinal cancer that perforates the bowel wall will seed itself in a random fashion on peritoneal surfaces nearby the site of perforation. In contrast, mucinous tumours, especially those that are minimally invasive, do not immediately adhere, implant, and progress. Mucinous cancer cells within the peritoneal space migrate so that their pattern of growth has been described as redistribution.[1] Mucinous tumours from many different sources may have this characteristic peritoneal surface distribution. The most frequent example is the pseudomyxoma peritonei syndrome that results from the perforation of an appendiceal adenoma.

The natural history of pseudomyxoma peritonei has caused much confusion. The term was first used by Werth in 1884 to describe a massive intraperitoneal accumulation of mucinous tumour; he associated the condition with an ovarian mucinous tumour of low biological aggressiveness.[2] Unfortunately mucinous tumour widely distributed throughout the abdomen and pelvis from numerous different primary sites has been referred to as pseudomyxoma peritonei. These heterogeneous tumour types include rapidly fatal diseases as well as indolent tumours that slowly progress over several years, even decades. Nevertheless, even though the disease may have a long natural history and rarely disseminates to lymph nodes or to the liver, in the absence of special treatments all patients die of pseudomyxoma peritonei.[3] In order to more precisely define this disease regarding treatment options and prognosis with cytoreductive surgery, Sugarbaker *et al.* defined the pseudomyxoma peritonei syndrome.[4] In this syndrome the mucinous tumour had a characteristic distribution within the abdomen and pelvis and the primary tumour was a perforated appendiceal adenoma. Ronnett *et al.* showed that the primary tumour in women was a perforated appendiceal adenoma even though the ovarian involvement was massive.[5]

With these mucinous tumours three different physical parameters control the distribution of tumour.[6] First, resorption of peritoneal fluid will cause tumour cells to accumulate at a particular site. This is true of the lymphoid accumulations within the greater omentum, lesser omentum, and the junction of small bowel and small bowel mesentery. A mucinous tumour accumulation beneath the right hemidiaphragm occurs from peritoneal fluid resorption at the lymphatic lacunae at this site. A second mechanism is gravity which will tend to fix

Correspondence to: Paul H. Sugarbaker, MD, FACS, FRCS, Director, Surgical Oncology, Washington Cancer Institute, 110 Irving St., NW, Washington, DC 20010, USA. Fax: (202) 877-8602; E-mail: Paul.Sugarbaker@medstar.net

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tumour cells at dependent sites within the abdomen and pelvis. Mucinous tumour masses in the pelvis and right retrohepatic space are examples of gravity-dependent distribution. Other examples of gravity-dependent tumour accumulations are the dependent area created by the left colon and left paracolic sulcus, the cul-de-sac created by the ligament of Treitz, and the ileocecal valve region. Our observations suggest that the subpyloric space accumulates mucinous tumour by this mechanism. The third mechanism controlling mucinous tumour accumulation is fibrin entrapment. In this situation, prior surgery and the abraded (sticky) peritoneal surfaces that result will cause cancer cells to accumulate within the fibrin clot at the injured site.

The purpose of this manuscript is to describe the mucinous tumour accumulations that are repeatedly observed within the omental bursa posterior to the pylorus, and to suggest a mechanism whereby tumour accumulates at this site, and to document the peritonectomy that is required to complete a cytoreduction with tumour in this anatomic site.

METHODS

Anatomic description

In performing cytoreductive surgery on 550 patients with pseudomyxoma peritonei syndrome an accumulation of tumour beneath the pylorus is significant surgically in approximately 15% of patients. This may progress to cause obstruction of the outlet of the stomach. The abdominal CT in Figure 1 shows the characteristic appearance of the tumour accumulation posterior to the stomach. Its borders are the pylorus and antrum of the stomach anteriorly, the duodenum to the right, and the head of the pancreas posteriorly.

Mechanism of tumour accumulation

An important issue in the pathobiology of mucinous peritoneal carcinomatosis concerns the mechanism whereby a large volume of disease accumulates posterior to the antrum of the stomach. The mechanisms whereby the distribution of mucinous tumour occurs at other sites within the abdomen and pelvis should also explain the large deposits posterior to the pylorus.

In repeatedly clearing mucinous tumour from this site it was established that the tumour was within the lesser sac and could not be approached from the peritoneal cavity. The retropyloric tumour mass was confluent with that occurring on the floor of the omental bursa. The two most prominent mechanisms controlling large tumour accumulations are gravity and peritoneal fluid resorption. There is no known site for peritoneal fluid resorption within the omental bursa. However, mucinous tumour cells would be expected to enter the lesser sac in a random fashion as they migrate within the peritoneal cavity. Gravity would cause local accumulations of these mucinous tumour cells within the lesser sac. The first portion of the duodenum creates an anatomic barrier that results in a cul-de-sac just inside the foramen of Winslow. By gravity single tumour cells would preferentially accumulate within this space and as they progress result in a large mass at this site. Our hypothesis is that tumour accumulation within the subpyloric space occurs by gravity effect on tumour cells entering through the foramen of Winslow (Fig. 2).

Cytoreduction of mucinous tumour from the subpyloric space

In performing cytoreductive surgery five peritonectomy procedures are performed using a centripetal approach: greater omentectomy–splenectomy, left subphrenic peritonectomy, right subphrenic peritonectomy, lesser omentectomy–cholecystectomy, and complete pelvic peritonectomy.[7] If these dissections can be completed then surgical strategies for clearing the mucinous tumour from surrounding the stomach and first portion of the duodenum should be considered. If the vascularity of the stomach can be preserved by sparing the left gastric artery and vein, then a subpyloric peritonectomy should be performed. If there is compromise of these vessels by a large volume of tumour densely adherent to the distal stomach, then total gastrectomy is necessary.

To resect the subpyloric tumour accumulation the first portion of the duodenum is dissected free by ligating and dividing the branches of the right gastroepiploic and right gastric vessels. By blunt dissection the first portion of the duodenum is then freed of mucinous tumour. A linear cutting stapler is used to divide the duodenum just distal to the pylorus. With traction on the stomach specimen the peritoneum with adherent mucinous tumour is dissected away from the head of the pancreas. Similarly, tumour and peritoneum are electroevaporated from the caudate process and left side of the inferior vena cava.[8] The floor of the omental bursa is bluntly stripped toward the left gastric vessels. After dividing the phreno–esophageal ligament the gastroesophageal junction is divided using a linear cutting stapler. As a final step in the gastrectomy the left gastric vessels are ligated and suture ligated.

Reconstruction following total gastrectomy with extensive cytoreduction

The reconstruction following total gastrectomy in a patient with extensive cytoreductive surgery is staged. Following the gastrectomy the patient receives intraperitoneal chemotherapy using mitomycin C at 41°C and continuous manual manipulation.[9] Then the oesophago–jejunostomy and other anastomoses to

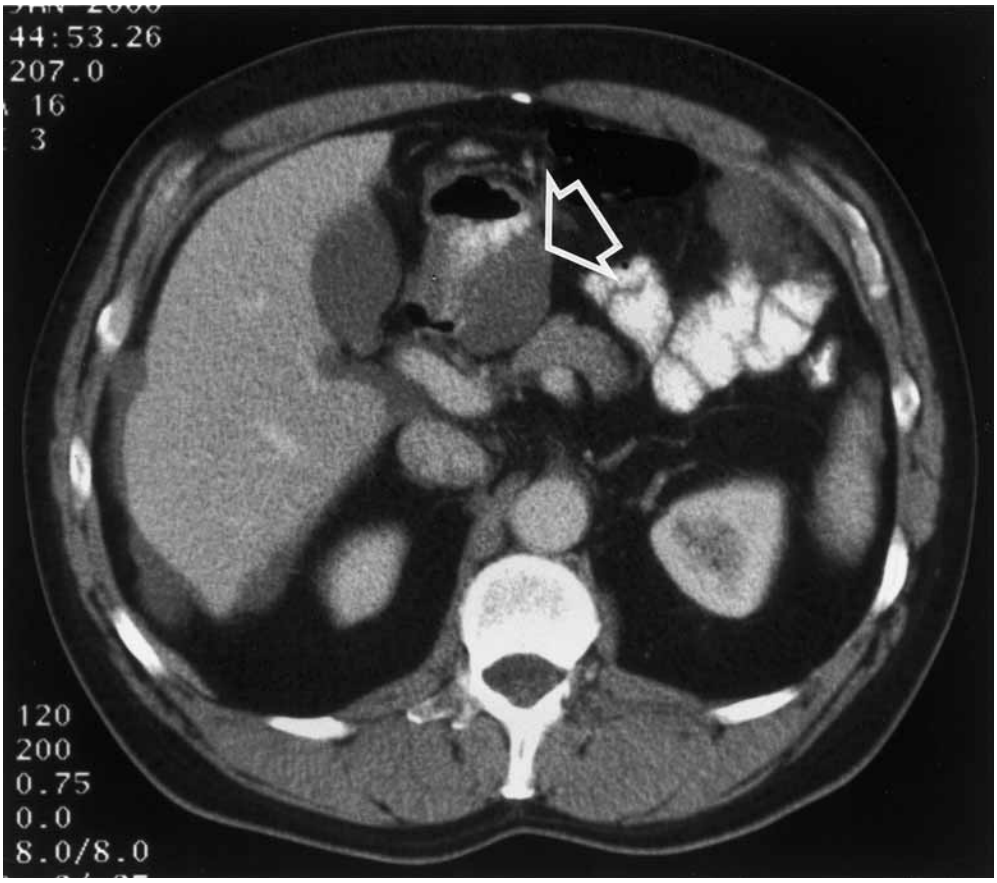

Figure 1 The subpyloric space is seen on the CT scan of a patient with widespread mucinous tumour from a perforated appendiceal malignancy. The histology showed a hybrid type of tumour with areas of both adenomucinosis and mucinous adenocarcinoma present. Its removal required total gastrectomy. Both the left gastric artery and vein were intimately involved by the tumour mass.

establish intestinal continuity are performed. The entero–enterostomy, in order to complete the Roux-en-Y reconstruction, is not performed. A temporary diverting jejunostomy is performed.[10] Post-operatively the patient receives early post-operative intraperitoneal 5-fluorouracil. At approximately 6 months this diversion is closed. At the time of ostomy closure a second-look procedure and an additional cycle of peri-operative chemotherapy is used. Short-term results of treatment of 50 patients have been excellent and morbidity and mortality acceptable; long-term evaluation of total gastrectomy for pseudomyxoma peritonei syndrome is pending.[10]

DISCUSSION

The subpyloric space is the most dependent portion of the omental bursa in an erect patient. Its position within the lesser sac is similar to the cul-de-sac (Douglas pouch) within the larger abdominopelvic space. Accumulation of tumour in a dependent fashion directed by gravity causes the relatively large volume of tumour to develop at the lowest point within the lesser sac.

The mucinous tumour in the subpyloric space has often been thought to represent perigastric lymph-node metastases. If it were lymph nodal dissemination then the gastrectomy would not be indicated. In our database of 655 patients only three patients have had lymph nodal metastases from the tumour that surrounds the stomach and the left gastric vessels. In this situation the prognosis has been extremely guarded. These patients have gone on to recur despite complete cytoreduction. However, in those patients where peritoneal surface malignancy is contained within the subpyloric space the celiac lymph nodes are not dissected except to facilitate the total gastrectomy dissection.

In the past extensive perigastric tumour was consistently associated with an incomplete cyto-reduction. In these patients serial debulking was associated with a median survival of approximately 3 years and a 5% 5-year survival.[3] Options to complete cytoreduction with intraperitoneal chemotherapy may be debulking surgery combined with systemic chemotherapy.[11] In the past total gastrectomy had not been utilized as a visceral peritonectomy procedure. We now consider this the fifth standardized peritonectomy

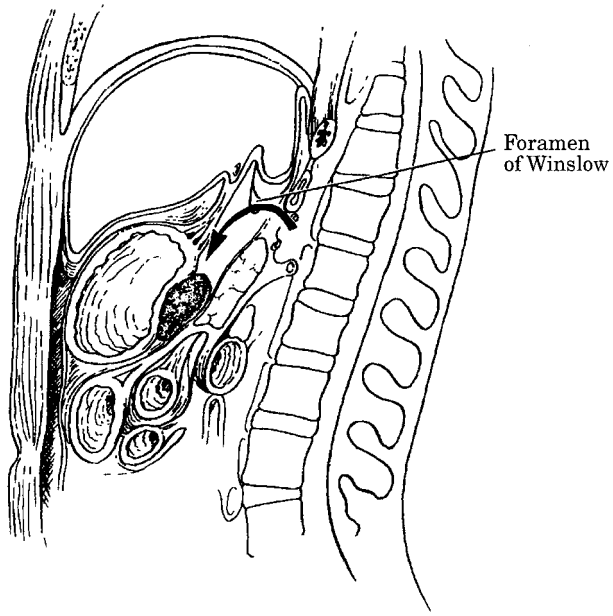

Figure 2 Mechanism whereby the subpyloric space becomes involved by tumour cell redistribution is shown. As migratory tumour cells enter the foramen of Winslow, they will by gravity accumulate within the first dependent site. This is the subpyloric space.

procedure complimenting the other peritonectomy procedures presented in the past that may result in a complete and possibly curative treatment.[7] The gastrectomy is indicated if all other peritonectomy procedures are complete and the perigastric mucinous tumour remains the only impediment to a complete cytoreduction.

Special precautions need to be observed if total gastrectomy is to be added to an extensive cytoreduction with perioperative intraperitoneal chemotherapy. The long delay in the resumption of gastrointestinal motility demands that the gastrointestinal tract be defunctionalized. If bile and enzymes accumulate in large quantities in the proximal jejunal segment, a high likelihood of esophago–gastric anastomotic insufficiency occurs. Also, several other intestinal anastomoses may be required. Small bowel anastomoses and small bowel to colon or to rectum are frequently necessary. A diversion of the bile and pancreatic secretions for approximately 6 months allows for secure healing of all intestinal anastomoses with a low anastomotic leak rate. The staged reconstruction is indicated for long-term maintenance of partial bowel rest.

The major complication that has been observed in this group of patients is pancreatitis. The investing fascia of the pancreas is removed completely. Sometimes, the mucinous tumour will invade the anterior aspect of the pancreas. The dissection that is utilized must be electroevaporative surgery or the positive margins will recur.[7] A minimum of two closed-suction drains at the lower aspect of the pancreas and in the left upper quadrant are indicated in order to remove any enzyme-rich material that may leak from the surface of the pancreas.

This cytoreduction, if complete, must be combined with perioperative intraperitoneal chemotherapy if there is to be a long-term disease-free survival. We have used heated intraoperative intraperitoneal mitomycin C.[9] In addition, early post-operative intraperitoneal 5-fluorouracil is used in a majority of these patients. One exception is the very minimally aggressive adeno-mucinosis type of pseudomyxoma peritonei. In these patients the early post-operative intraperitoneal 5-fluorouracil is usually withheld. The heated intraoperative mitomycin C is given in all other patients.

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