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Numerical and experimental analysis of factors leading to suture dehiscence after Billroth II gastric resection

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ABSTRACT

The main goal of this study was to numerically quantify risk of duodenal stump blowout after Billroth II (BII) gastric resection. Our hypothesis was that the geometry of the reconstructed tract after BII resection is one of the key factors that can lead to duodenal dehiscence. We used computational fluid dynamics (CFD) with finite element (FE) simulations of various models of BII reconstructed gastrointestinal (GI) tract, as well as non-perfused, ex vivo, porcine experimental models. As main geometrical parameters for FE postoperative models we have used duodenal stump length and inclination between gastric remnant and duodenal stump. Virtual gastric resection was performed on each of 3D FE models based on multislice Computer Tomography (CT) DICOM. According to our computer simulation the difference between maximal duodenal stump pressures for models with most and least preferable geometry of reconstructed GI tract is about 30%. We compared the resulting postoperative duodenal pressure from computer simulations with duodenal stump dehiscence pressure from the experiment. Pressure at duodenal stump after BII resection obtained by computer simulation is 4–5 times lower than the dehiscence pressure according to our experiment on isolated bowel segment. Our conclusion is that if the surgery is performed technically correct, geometry variations of the reconstructed GI tract by themselves are not sufficient to cause duodenal stump blowout. Pressure that develops in the duodenal stump after BII resection using omega loop, only in the conjunction with other risk factors can cause duodenal dehiscence. Increased duodenal pressure after BII resection is risk factor. Hence we recommend the routine use of Roux en Y anastomosis as a safer solution in terms of resulting intraluminal pressure. However, if the surgeon decides to perform BII reconstruction, results obtained with this methodology can be valuable.

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1. Introduction

Computer simulations today are almost common medical tool used for prediction and sophisticated medical diagnostics. In conjunction with modern medical devices used for data acquisition computer simulation can be used for theoretical consideration and education, and also as a patient specific medical diagnostical tool. Multidisciplinary approach in medicine is necessary due to need of cooperation between medical doctor, computer scientist and engineer [1]. Using this modern tool medical doctors can perform their interventions more easily and safely. Due to limited hardware resources as well as software and medical acquisition devices, in the beginning computer scientists were not able to simulate complicated systems such as soft tissue organs with many physiological functions. That is the reason why first steps were made in the field of orthopedics and maxillofacial surgery where the problem could be solved with less powerful computer simulation [2,3]. In this study advantages of multidisciplinary approach were shown in the field of gastrointestinal surgery. We used three-dimensional computer simulation in regard to the real anatomical state in a human body. The duodenum is the first part of the small intestine with sensitive, motor and secretory functions regulated by neurological and hormone-dependent mechanisms [4–8]. Very important role of duodenum and pyloric sphincter becomes especially evident after surgical interventions on the gastroduodenum [9,10].

Many authors researched complex feedback mechanisms in physiological state, but in this study our interest was to investigate how surgical intervention changes these mechanisms [11–13]. Experienced surgeons ex juvantibus know that geometry of gastroduodenum after Billroth II gastric resection is very important, but we tried to precisely numerically quantify influence of this factor [14]. According to literature insufficient attention has been paid on how geometry of the reconstructed gastroduodenal region influences pressure distribution and afferent loop syndrome that may cause duodenal stump blowout.

There are various types of reconstruction after distal gastric resection, although Billroth II with omega jejunal loop and Roux en Y are most common. Billroth II gastric resection represents anastomosis (artificial connection) between the gastric stump and a loop of jejunum (gastrojejunal anastomosis, gut to side), and this type of intervention is the subject of our study. The afferent loop conducts duodenal juice toward the gastric stump and the rest of the intestine. The distal or efferent loop is the part of the duodenum that is downstream of the anastomosis, and it conducts duodenal and gastric stump content distally to the small intestine. The anastomosis is antecolic when the jejeunal loop is positioned in front of the transverse colon, or the jejunal loop may be brought up posteriorly through an opening made in the transverse mesocolon (retrocolic anastomosis). There are other methods of gastrointestinal tract reconstruction after gastric resection, and one of these is called Roux en Y gastrojejunoanastomosis, in which the small bowel is cut distal to the ligament of Treitz, and the anastomosis is created between the distal limb of the jejunum and remaining gastric tissue (or esophagus in cases of total gastrectomy). The proximal limb of the jejunum is positioned downstream to the jejunum at a distance of at least 45 cm, where a termino-lateral end-to-side anastomosis is created. Dehiscence is a surgical complication in which surgical suture ruptures. In both of surgical interventions mentioned above dehiscence is the most dangerous complication (leading to peritonitis and sepsis) [15]. It is well known that after Billroth II gastric resection duodenal stump leakage and blowout is much more frequent than in case of reconstruction using Roux en Y jejunal limb [16].

Standard reoperative procedure in case of afferent loop syndrome involves conversion to Roux en Y type of reconstruction by cutting afferent limb immediately proximal to an obstruction and creating gastrojejunal reanastomosis using 45–75 cm long loop of the jejunum. Roux en Y gastrojejunostomy is also better in controlling dumping and bile reflux gastritis. Because there are not enough data from definite prospective randomized studies, surgeon preference often dictates the type of reconstruction [17]. Billroth II gastric resection is surgical intervention where omega jejunal loop is attached to gastric remnant (gastrojejunal anastomosis) and this type of intervention was the subject of our study (Fig. 1). We tried to get numerical proof that pressure in the afferent loop after Billroth II gastric resection is relatively high and it could be one of the main factors that cause duodenal dehiscence.

The length of the afferent loop is variable and depends on anatomical variations (e.g. length of the mesenterium of the small intestine and adhesions), as well as the surgeon's preferences. There is a hypothesis that increased intraluminal pressure in the afferent loop is the dominant cause of duodenal stump dehiscence, that was our main subject of interest in this study. Possible causes of afferent loop syndrome are the length of afferent jejunal loop, narrow gastrojejunoanastomosis, insufficient peristaltic movements, etc. [18–20].

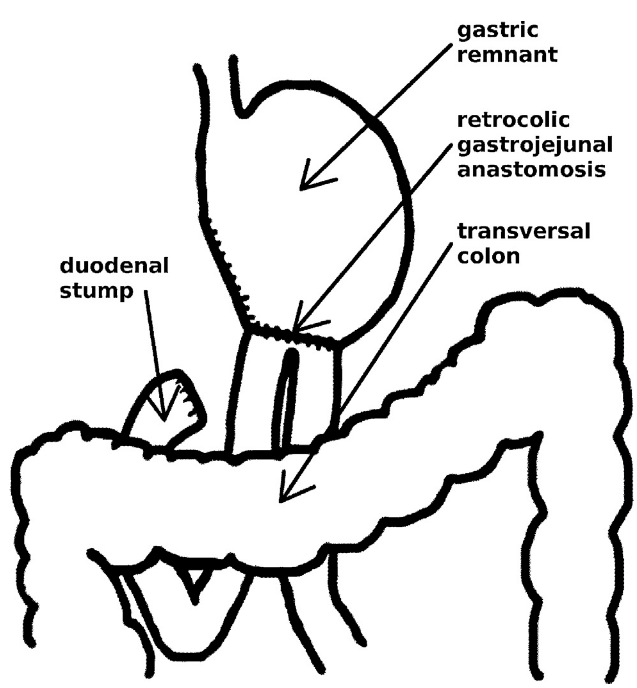

Fig. 1 – Billroth II gastric resection.