Preoperative Virtual 3D Modeling and Planning for Splenectomy

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Abstract: *Objectives*: To explore the possibilities of preoperative 3D modelling and analysis system based on multislice computed tomography data, to evaluate its effectiveness in performing laparoscopic splenectomy for the primary immune thrombocytopenia.

Methods: A patient, (61 yrs) with the diagnosis of idiopathic thrombocytopenic purpura, recurrent course. For 10 years she had been observed and underwent the numerous courses of conservative treatment; she also took daily 60 mg of prednisolone. The blood platelet levels reduced below $30×10^9$/l. The splenectomy was indicated due to the failure of conservative treatment. Multislice computed tomography with contrast bolus was performed. For preoperative planning a color 3D model of the surgical site was created on the basis of the obtained data in the "Autoplan" system. Systems giving the ability to plan surgical intervention combines the medical equipment, PACS system (picture archiving and communication system) available onsite advanced image-viewing workstations that can guide physicians; the ability to view images from various workstations via the network including the navigation enabling physicians to create the accurate and realistic models from stereo cameras, and to use computers as well as mobile computing devices directly in the operating room. The patient was underwent laparoscopic hybrid splenectomy.

Results: According to the 3D model a main type of vascularization of the spleen was revealed. The distal part of the pancreatic tail did not reach (1.5 cm) the gate of the spleen. Accessory spleens and periprotsess were absent. The data of 3D model were confirmed intraoperatively and allowed performing a laparoscopic hybrid splenectomy without technical difficulties precisely with a minimal blood loss. The postoperative period was uneventful. The patient was discharged on the 5th day in a satisfactory condition. The parameters of platelet level have reached the reference values (356×109 /l).

Conclusion: Preoperative 3D modelling permits the surgeon to make pre-operative planning and provides him with important information on individual topographic and anatomic features in forthcoming operation sites. The information about the individual characteristics of the splenic vascularization and pancreatic topography in its gate lets to allocate and ligate vessels precisely, that improves the quality of hemostasis and also reduces the probability of the pancreatic injury. Preoperative visualization of accessory spleens increases the radicalism of the surgery.

Keywords: Splenectomy, thrombocytopenia, computer tomography, 3D modelling, hemostasis, vascularization.

INTRODUCTION

A splenectomy is indicated for the management of patients with idiopathic thrombocytopenic purpura in the case of inability of conservative therapy; 80% of patients recover without special treatment. Splenectomy is so-called "second line" of ITP therapy in case of resistance to corticosteroids [1]. Nowadays laparoscopic splenectomy is emerging 'gold standard' treatment, characterized by better treatment outcomes in contrast to congentional laparotomy [2].

To improve the treatment outcomes the embolization of splenic vessels is sometimes used which enable to reduce the risk of intraoperative bleeding [3]. However, according to various authors' reports the number of conversions to laparotomy, especially at the mastering stages reaches 15-25%.

The intra-abdominal bleeding from unligated vessels not visualized within the operation is a major cause for conversion to laparotomy; the development of new surgical approaches have been required [4].

Prediction of the splenectomy efficacy and selection of the optimal surgical access based on topographic and anatomical features of the surgical site is certainly of great importance. Technology of three-dimensional (3D) medical images of computed tomographic (CT) data has become widely used in the diagnosis within recent decade [5, 6].

A new trend of today's surgery is considered to be a preoperative modeling of the surgery site [7]. Systems for design of 3D modeling with possible intraoperative navigation are actively being studied at present, particular, in thermal ablation of metastases to the liver in colorectal cancer [8], and also widely used in creation of surgical virtual simulators [9]. In the Center of breakthrough research of Samara State Medical University, "Information Technologies in Medicine," the

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group of specialists, including surgeons, radiologists and programmers conducts the collaborative development and implementation of software package "Autoplan" giving the ability to plan surgical intervention with a possibility of semi-automatic segmentation. At the same time the parenchymal organs, arteries and veins are separately segmented in the corresponding phases of contrasting.

Systems giving the ability to plan surgical intervention combines the medical equipment, PACS system (picture archiving and communication system) available onsite advanced image-viewing workstations that can guide physicians; the ability to view images from various workstations via the network including the navigation enabling physicians to create the accurate and realistic models from stereo cameras, and to use computers as well as mobile computing devices directly in the operating room. Samara State Medical University has accumulated positive experience of using preoperative 3D modeling; particularly it concerns the operations for volumetric liver formations [10].

OBJECTIVES

To study the efficacy of the method of volume visualization in surgery (preoperative 3D modeling) based on captured CT scan digital data in performing laparoscopic splenectomy for the primary immune thrombocytopenia.

RESULTS

The experience of using preoperative colored 3D model of the operation in the surgery on the spleen is analyzed in this clinical observation. A 61-year old man remaining thrombocytopenic due to ITP for 10 years.

For a long time she has been treated conservatively but ineffectually by hematologists in the Clinics of Samara State Medical University. The diagnosis of the primary immune thrombocytopenia was verified by hematologists according to the survey protocol of the patients with thrombocytopenia [1]. Anamnestic platelet count reduced up to 10×109 /l, constant nasal and gingival bleeding and subcutaneous bleeding occured. Due to the permanent histories of periodontal disease the patient has lost most of the teeth. The patient took 60 mg of prednisone daily for the recent year. Long-term anamnesis, failure of conservative therapy, low platelet count despite high doses of glucocorticoids, the threat of intracranial hemorrhage were considered to be the indication for surgical treatment – splenectomy.

On admission to a surgical department of the Clinic of hospital surgery of Samara State Medical University, the marked clinical signs of the Itsenko-Cushing's syndrome were registered in the patient, the platelet count was 36×109 /l, numerous bruises were visualized on the body. Objectively: general state of a patient was closer to satisfactory, numerous subcutaneous bleedings on the skin of limbs, and some fat deposits and stretch marks typical for corticosteroids overdose were observed on the body and face. A persistent hypertension (180 and 100 mmHg), tachycardia up to 110 beats per minute were noted. Ultrasound examination of the abdominal organs showed the signs of chronic cholecystitis and chronic pancreatitis. The spleen had normal dimensions 95×45 mm.; its area was 38,8 mm2. Changes of echostructure and focal splenic lesions were not revealed. The fibrogastroduodenoscopy showed some signs of an erosive hemorrhagic gastritis. A postoperative multislice computed tomography of the abdominal
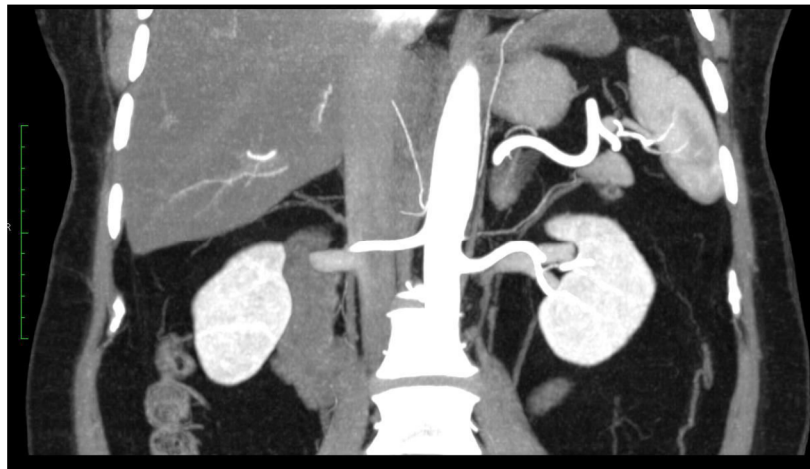

Figure 1: Computed tomography in the coronal plane. Arterial phase in the maximal intensity projections: 10 mm thickness.

organs (tomograph TOSHIBA (Aquilion 32 (Japan) with a bolus of contrast medium) was carried out, 100 ml of low-osmolar iodinated contrast media via the elbow catheter was introduced (Figures **1**, **2**).

In the "Autoplan" system the color CT-based 3D model of the upcoming surgery was designed (Figures **3**, **4**).

On the basis of this model the possibility of performing standard laparoscopic hybrid splenectomy was predicted. According to the designed model no

vascular abnormalities, accessory vessels or accessory spleens, peritoneal process, close location of the pancreatic tail to splenic hilum have been detected. The patient underwent the hand-assisted laparoscopic hybrid splenectomy using Hand Port. Surgery was conducted under combined endotracheal anesthesia; the patients were positioned in left lateral position with a roller.

During the surgery three ports were installed: 1 – Hand Port in the left subcostal area parallel and 3 cm below the left costal arch margin; Port 2 (10 mm) for

Figure 2: Computed tomography in the coronal plane. Venous phase in the maximal intensity projections: 10 mm thickness.
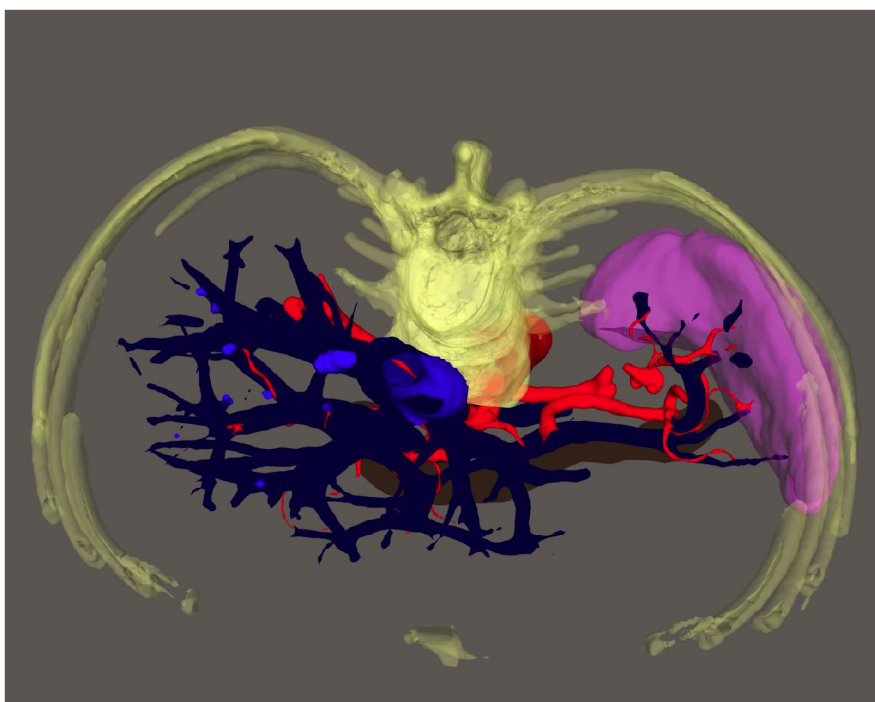

Figure 3: Polygon 3D-model. View from above. Bones, spleen, pancreas, arteries and veins are marked with different colors.

Figure 4: Polygon 3D-model. Front view. Bones, spleen, pancreas, arteries and veins are marked with different colors.

insufflation and video system with a visual angle of 30° in the left mesogastric area 3 cm above the navel; Port 3 (15 mm) in the left side to introduce the working tools – harmonic shears, clipper and suturing device.

Mobilization of the spleen was performed by means of ultrasonic shears from the lower to the upper pole along the lateral spleen surface. Some vessels were clipped and crossed. The pedicle of the spleen was sewed and cut off with the endoscopic sewing-cutting device with a blue cassette (suture length – 45 mm, staples height – 3.5 mm). The spleen was removed from the abdominal cavity through HandPort. Revision of the spleen bed for accessory spleens was obligatory. Intraoperative blood loss was less than 50 ml. The patient was installed the control drainage of the splenic bed through the lateral port. The duration of surgery was 75 minutes.

This postoperative period was significantly different from those where patients were operated on via the laparotomy access. In the early incisional period after the laparoscopic hybrid splenectomy a minimal pain syndrome was registered, and administration of narcotic analgesics was not required. By the end of the first day the patient was activated. The intestinal function was restored in a day. Abdominal drainage was removed on the 3rd day. Totally about 100 ml of

serous-hemorrhagic discharge was secreted via the drainage. The postoperative period was uneventful. The patient was discharged on the 5th day with normal platelet count (356×109 /l). Doses of Prednisolone were reduced according to the scheme until treatment discontinuation. The patient was assessed one month after the surgery. There were no complaints. The satisfactory state was registered. Platelet count was 325×109 /l. Ability to work was fully restored.

DISCUSSION

Spleen surgery is one of the least explored sections of the abdominal surgery. The recent studies concerning the function of this organ have shown its critical role in supporting the body's normal immune and hematopoietic status. Nowadays in case of the spleen pathology the organ-saving operations have replaced the conventional splenectomy. However, in hematological patients splenectomy must be done and all accessory spleens be sought and removed. The modern development of medicine involves the use of high-tech diagnostic equipment and the application of new methods in clinical surgery. A laparoscopic splenectomy may well be considered the surgical treatment of choice in hematology.

But is it always possible to perform it and where is the limit of endovideolaparoscopic technologies? When

should the preference be given to a conventional laparotomic operative technique?

Undoubtedly, common sense and safety principle should not yield to the desire of the surgeon to perform the operation laparoscopically by all means. Preoperative knowledge of topographic and anatomical features of the operative site by the surgeon is, without any doubt, of great importance and able affect the choice of splenectomy method.

Surgical Department of the Clinic of Hospital Surgery of Samara State Medical University has experience of performing over 500 splenectomies in patients with hematological diseases; however, surgical selection criteria for the operation approach were mainly determined on the basis of surgeon's personal preference or empirical experience. Currently, objectivisation and standardization are needed in the choice of the operative treatment method in hematological patients. Indications and contraindications to the laparoscopic technique are relative.

The authors assume that the preoperative color 3D modeling may become one of the objective selection criteria of the splenectomy. For example, in the case of revealing of large sizes of the spleen, multiple accessory spleens, atypical vascularization of an organ, abnormal anatomic relationships, a conventional surgery likely confers a more expedient. Conversely, minimally invasive surgery is reliably performed in the uncomplicated topographic anatomical picture. Multislice computed tomography with the bolus contrasting is a standard tool for the diagnosis of the spleen diseases. The method permits to differentiate benign and malignant tumors, to determine their vascularization and topographic-anatomic relationships with various vascular structures and the pancreas.

According to CT information and the analysis of data in the system "Autoplan" of the color 3D model the patient had the main type of vascularization of the spleen. Splenic vein was formed from four venous trunks.

Splenic artery was also divided into four smaller branches. The tail of the pancreas did not reach the splenic hilum (1.5 cm). No accessory spleens and peritoneal process around it was found.

The obtained information of those reconstruction models were totally confirmed within the surgery and thus allowed performing a hybrid laparoscopic

splenectomy precisely with minimal blood loss. Knowledge of the pancreatic tail topography helped to avoid intraoperative injury with possible development of the postoperative pancreatitis. In the domestic literature the issue of 3D modeling is presented fragmentary. The monograph "Virtual surgical simulation on the basis of the computer tomography data" had some limitations due to the equipment defects at the stage of the research implementation: single-slice spiral computed tomography was used; to get an accurate arterial and venous phases of contrasting was impossible due to the low speed of the tube rotation [11].

The presented clinical observation is our first experience on the spleen surgery and allows making only preliminary optimistic conclusions. Undoubtedly, this line of research is promising; it requires further study, multidisciplinary approach and active implementation.

CONCLUSION

Due to preoperative 3D modeling the surgeons enable to evaluate their preoperative planning decisions and understood better the surgical operations, taking into account the knowledge about individual topographic and anatomical features of the surgery site.

Knowledge of the individual characteristics of the splenic vascularization and pancreatic topography permits to allocate precisely and to ligate the vessels, to improve hemostasis and to reduce the probability of pancreatic injury. Preoperative visualization of accessory spleens increases the radicalism of the operation.

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