The spleen is an odd organ of the abdominal cavity located in the left epigastrium. In adult patients the size of the spleen may reach 11cm, weighing between 150 and 200g, being dependent of the blood supply. Its long axis under anatomical conditions runs along the tenth rib with the following organs in its vicinity: the stomach, left kidney, and pancreatic tail. It is limited by the diaphragm and colon. Vascularization is derived from the largest branch of the celiac trunk—the splenic artery, which supplies the organ by means of the hilum. The spleen is stabilized by the following three ligaments: gastrosplenic, phrenicosplenic, and phrenicocolic, as well as the splenic capsule consisting of collagen and elastic fibers, and smooth muscle cells. An accessory spleen is diagnosed in nearly 20% of patients, mostly located in the vicinity of the main spleen (54%), as well as on the major curvature of the stomach (25%), greater omentum (12%), pancreatic tail (6%), and splenocolic ligament (2%) (1). Considering the structure and function of the spleen the above-mentioned exists as two organs. The white splenic pulp, which consists of periarterial lymphatic sheaths and germinal centers acts as an immunological organ. The red splenic pulp consisting of macrophages and granulocytes acts as a phagocytosis organ.

**NEOPLASMS OF THE SPLEEN**

Numerous molecular studies demonstrated that each cell of the body has oncogenic potential and under favorable conditions might be subject to neoplastic transformation. In case of the spleen malignant lesions are rarely diagnosed. Primary benign tumors located in the spleen include hemangioma, lymphangioma, littoral cell angioma, splenic cysts, and solid lesions, such as hamartoma and inflammatory tumors. Their epidemiology and etiology remains unknown. Early treatment is connected with a very good therapeutic effect. Primary malignant tumors of the spleen include lymphomas and angiosarcomas (2). The above-mentioned are very aggressive in nature and prognosis, regardless the therapeutic method, is serious. Primary splenic angiosarcoma is a very rare disease entity with a high potential of metastasis, amounting to 70-100% (3). Splenic lymphomas are a very heterogenous group of tumors. The last report from the World Health Organisation (WHO) described the latter as PSL/SMZL (primary splenic lymphoma/splenic marginal-zone lymphoma) (4). Their diagnostics is complex and mostly consists of cytogenetic and immunophenotyping examinations. Based on their results lymphomas are classified and the decision concerning appropriate treatment is undertaken. Another diagnostic difficulty in case of lymphomas is the determination of the primary lesion, because most often they are part of the diffuse neoplastic process (5, 6). Tumors of the organs might also metastatize to the spleen including the ovaries, lungs, stomach, liver, and skin. Metastatic lesions usually spread via blood...
circulation. However, metastases by means of the lymphatic system and by the continuity were observed (7, 8).

**CHARACTERISTICS OF SPLENECTOMY**

The preparation of the patient for elective splenectomy is usually limited to standard presurgical procedures. Additional care should consider patients with splenomegaly and hypersplenic thrombocytopenia. The importance of hematological protection is worth emphasizing. Patients may often present a low platelet count, due to their splenic destruction. Their rapid supplementation is difficult, with unsatisfactory effect. Therefore, platelet transfusions are recommended after splenic artery ligation. Moreover, the presence of antiplatelet antibodies might hinder the effective substitution leading towards the implementation of corticosteroid therapy (9).

In case of elective splenectomy the patient should receive a polyclonal vaccine against the capsular antigens of three bacteria: Streptococcus pneumoniae, Haemophilus influenza and Neisseria meningitidis. This is especially important in case of children. Due to the significant role of the spleen in case of immunological processes, it is recommended to perform elective splenectomy when the child is 4-6 years old. If delayed surgery is not possible or in case of emergency splenectomy, vaccinations should be performed after the operation considering partial splenectomy. Total resection is a common and technically simple method. However, the availability of novel surgical techniques also enables to perform partial resections. The decision concerning the scope of the resection depends on the type and stage of the tumor, patients' clinical condition, and hemostatic possibilities (efficiency). The surgical procedure should be performed by an experienced surgeon, and the final decision should be undertaken together with the hematologist-oncologist.

The most common complications after splenectomy may be divided into general and hematological complications. General complications include pneumonia, pulmonary atelectasis, pleuritis, gastrointestinal bleeding, venous thrombosis, hematuria and urinary tract infections, pancreatitis, wound infections and subphrenic abscess. Hematological complications include transient lymphocytosis, increased platelet count (400-500 × 10⁹/l), and temporary reduction in the production of antibodies. The above-mentioned are not related to the choice of the surgical technique, but merely result from splenectomy, the patients' individual characteristics, and location of the spleen. General complications require vigilance and conservative or surgical management, depending on their type. Hematological complications are usually temporary. The number and ratio of red blood cells did not change after splenectomy and high platelet values may persist for up to a year after the procedure. This is not an indication for the use of anticoagulants. However, it seems appropriate to administer antiaggregative drugs, due to the increased risk of thrombosis. Depending on the patients' immunological system and prior immunization the possible infectious complications should be considered. Most patients, particularly young people, receive prophylactic penicillin for a period of one year (10).

**Classical splenectomy**

The first documented splenectomy was performed in 1549 in Naples by Zacarelli. Forty years later Rosetti performed the first successful classical splenectomy (11). There are two basic methods considering splenectomy, and the choice of the technique depends on the potential blood loss and condition of the splenic capsule (danger of hemorrhage after its rupture). Posterior splenectomy is performed in case of traumatic splenic rupture and consists in the clamping of splenic vessels from the hilus approach. It is definitely faster but more dangerous. In elective cases when the spleen is significantly enlarged anterior splenectomy is performed. The organ remains in situ and the splenic artery is ligated in first place. This enables significant blood outflow from the spleen by means of collateral circulation and the splenic vein. The next step consists in the ligation of the remaining vessels and spleen mobilization. Presented method may lead towards the development of complications associated with heart congestion in case of patients with a history of cardiac diseases. The second method is also not recommended in patients suspected of malignant lesions, due to the possibility of neoplastic blood stream dissemination (12).
Surgical treatment possibilities of splenic neoplasms – literature review

Laparoscopic splenectomy

The technique was first described in 1992 (13). Since then, laparoscopic surgery has become an increasingly popular technique for spleen removal. The method is recommended in patients with a normal sized spleen or if the organ is slightly enlarged. Currently, it is believed, that the dimensions of the spleen identified during the ultrasound examination should not be considered as an obstacle when performing the procedure. The only limitation in case of an enlarged spleen is the lack of experience of the surgeon. Contraindications include hypertension, decompensated coagulopathy, significant ascites, and severe splenic injuries. The laparoscopic procedure requires the surgeon to meet the many problems associated with the fragility and significant blood supply of the organ. Especially in case of oncological procedures when histopathological confirmation is required the above-mentioned seems to be a problem (14). Currently, two placements of trocars are used: lateral- as a standard and anterior- only in case of a significantly enlarged spleen (>23 cm or >3 kg) (15). The procedure begins with the introduction of trocars and search for and accessory spleen, depending on the experience of the surgeon, the number and type of trocars might change, and search for an accessory spleen. Afterwards, one may observe the mobilization of the phrenicocolic ligament, which enables to free the spleen from the left epigastrium before the renosplenic ligament is visualized. Blood vessels of the splenic hilus are closed by means of an endoscopic stapler, paying particular attention as not to damage the tail of the pancreas. Using a 12 mm trocar a bag is introduced, in order to pack the spleen. In case of splenomegaly one can think of parceling the spleen, devoid of vessels and tightly packed. However, in case of neoplastic suspicion the above-mentioned method is not performed. In case of proper hemostasis, many Authors believe that maintaining drains in the abdominal cavity is not required (16).

SILS splenectomy

Single incision laparoscopic surgery (SILS) is one of the most novel laparoscopic techniques, where the approach to the abdominal cavity is possible by means of a single incision (20mm), usually near the navel. After the operation the patient presents with only one scar. The first documented procedure by means of the above-mentioned method was a cholecystectomy performed in 1997. Based on available literature the SILS approach in case of splenic surgery was described eight times, and all studies were elaborated after 2009. The previously published results confirmed the safety of the procedure, however, current knowledge and experience are insufficient as to draw far reaching conclusions concerning procedure recommendations (17, 18, 19).

Hybrid splenectomy

Hybrid procedures rely on the combination of available surgical methods during one procedure, in order to optimize the undertaken treatment. One benefits from the combination of surgical techniques enabling the surgeon to operate, according to well-known and preferred methods, based on available equipment. Apart from the combination of the above-mentioned methods with the hybrid procedure one may observe in all cases hand-assistance. The above-mentioned broaden the scope of the surgical procedure by performing an additional incision, in order to introduce the hand into the abdominal cavity, which has both diagnostic and therapeutic implications. This sometimes seems to be a beneficial compromise between open and endoscopic surgery.

Robotic splenectomy

Robotic surgery is one of the newest surgical techniques. Thus far, only one company manufactures the hardware and software used in the above-mentioned procedures- the Da Vinci robot, Intuitive Surgical, Inc., Sunnyvale, CA, USA. Despite the relatively short time of use, the method has been applied in general and vascular surgery, operative urology and gynecology. Considering general surgery cholecystectomies are most commonly performed, while robotic splenectomy remains poorly validated. The procedure consists in the introduction of robotic arms into the abdominal cavity after prior formation of the pneumoperitoneum. The number of robotic arms depends on the type of the procedure and availability.
of equipment. The operator sitting at the console performs the procedure by means of very precise shifters, controlling the instruments, and observing the operative field in high-resolution 3D glasses. Moreover, an additional robotic canal is used, provided with a classical laparoscopic trocar, for the assistant standing at the operative table. Considering Polish conditions, only one center has the Da Vinci robot – The Specialistic Regional Hospital in Wroclaw.

NOTES splenectomy

Natural orifice transluminal endoscopic surgery (NOTES) is an operative technique enabling by means of an endoscope introduced into the natural openings (mouth, rectum, urethra, vagina), to perform surgery by making only an internal incision (stomach, intestine, bladder, vagina), leaving no scars on the patient. In addition to the conditions relating to the cosmetic effect the patient is rapidly mobilized, reporting less pain symptoms. The first appendectomy procedure by means of the NOTES method was performed in India in 2004 by G.V.Rao and N.Reddy. The transvaginal approach is the most common access to the abdominal cavity organs (20). This is associated with the ease of introducing the endoscope and decontamination, as well as provides safety with least observed problems in case of wound closure. Unfortunately, the vaginal approach can only be used in female patients. According to available medical literature only two NOTES splenectomies were performed (by means of the NOTES method). A 5 mm port was placed in the anterior axillary line and two 3 mm ports in the posterior axillary line. Colpotomy was performed in the vaginal fornix, visualization being possible by means of a 15 mm trocar. The spleen was released in a manner characteristic for laparoscopic procedures and extracted transvaginally in an endobag. The average duration of the procedure amounted to 180 minutes. The postoperative period proved uneventful (21).

CONCLUSIONS

Classical splenectomy is a well-known method considered as the „golden therapeutic standard” in case of many diseases of the spleen. The advantage of the method consists in the fact that it is simple to perform and does not require specialistic equipment. Disadvantages of the method include long hospitalization and prolonged postoperative analgesia, as compared to endoscopic procedures (22). Given the small trauma, laparoscopic splenectomy is recommended in patients with a normal or slightly enlarged spleen. As it turns out benefits of laparoscopic intervention in case of splenomegaly are not so obvious. Feldman et al. conducted a comparative study amongst 90 patients and demonstrated that benefits resulting from laparoscopic surgery referred only to patients with the size of the spleen ranging between 15 and 25 cm. In case of patients with myelofibrosis, due to the high probability of intraoperative bleeding laparotomy was most often performed (23, 24). A separate approach is required in case of suspicion of malignancy. Open splenectomy is the preferred method, due to the risk of splenic rupture, neoplastic cell dissemination, and possible hemorrhage (25).

In case of vascular tumors, which constitute the majority of neoplastic lesions localized in the spleen various therapeutic methods are available. Beginning with „watch and wait”, followed by the chemical and electrical embolization, and ending with surgical treatment (26). Due to the very high risk of severe bleeding laparotomy is the recommended method. An important factor in the decision-making to both of the above-mentioned situations (malignant and vascular lesions) is the experience of the surgeon. Maurus et al. came yet to another conclusion.

They postulated to try to perform endoscopic or laparoscopic procedures in all patients with indications for posttraumatic splenectomy. Because of the known and proven benefits of laparoscopic techniques and their safety, they should be frequently used. In case of difficulties or doubts surgery should be converted to classical laparotomy. Despite the fact that laparoscopy is burdened with disadvantages, such as two-dimensional (2D) vision and stiff instruments that may hinder the surgical procedure, opportunities provided by robotic surgery arise. In enables 3D vision using high-resolution glasses providing instrumentation beyond the capabilities of the human hand. These features are extremely useful during numerous surgical procedures. However, in case of procedures requiring precision, such as
partial splenectomy they seem not to be overestimated (27, 28). Robotic surgery uses the advantages and strong points of endoscopic procedures, additionally supplemented by the specific features pointed above.

One should also consider the high comfort of the operator. The disadvantage of the method is the instrumental limitation. Additionally, the overall cost following robotic treatment is high, and in case of splenectomy—very high (29). The enormous costs connected with the use of the Da Vinci robot are associated with the high price of equipment, and additional procedures. This situation may also be associated with the fact that only one company produces robots, thus, monopoly does not favor the perspective of cost reduction. Bodner et al. compared the costs of splenectomy performed by means of laparoscopy and robot-assisted. The median costs in case of robot procedures amounted to nearly 7000$, while that of classical laparoscopic splenectomy, slightly more than 4000$. The Authors additionally demonstrated the inconveniences resulting from the lack of availability of selected elements, for robotic procedures, such as stapler commonly used in classical surgery. Additionally, they recognized the significant drawback of the system consisting in the blockade of the possibilities of surgical table settings, before disconnecting the robotic arms, which in effect is essential to safeguard the patient from accidental injury, and should not be considered in terms of defect or system error (30). Robotic splenectomy cannot replace laparoscopy considering most indications, however, may be a valuable method in difficult cases, such as partial splenectomy, presence of liver cirrhosis, or difficult to resect, splenic tumors (31). Minimally invasive surgical techniques should continue to develop, although appropriate centers are required, which will have the potential to deal with innovative surgical techniques.

The above-mentioned discussion provides an overview of the available information concerning surgical treatment of splenic tumors showing the different techniques, based on the comparison criteria. The use of a particular therapeutic method must be individualized for each patient and the key selection criteria should include the experience and knowledge of the operating surgeon, type of lesion, and equipment availability. Most Authors when comparing the different surgical approach methods point to the lack of large multi-center randomized comparative investigations. This situation prompts questions and hypotheses, however, significantly makes it difficult or even impossible to draw authoritative conclusions.

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Received: 21.02.2012 r.
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