Background: New findings on immunological und haematological functions of the spleen, the postoperative risks following splenectomy, as well as improved surgical techniques resulted in an increased interest in organ preservative surgery after traumatic spleen injury in recent years.

Material and Methods: The data of all patients who underwent surgery for traumatic spleen injuries between 1995 - 2009 were recorded prospectively and analysed concerning type of operation, intra- and postoperative complications and the postoperative course.

Results: A total of 214 patients with splenic trauma underwent surgery. The spleen could be preserved in 80 patients (37.4%, group 1), using thermocoagulation, suture, glue sealant, splenorhaphy and partial spleen resection or combined techniques. 4 of those patients (5%) required a revision operation, in which two spleens could be salvaged by application of glue sealant. Eight of the patients of group 1 could be treated laparoscopically (10%).

Conclusion: Under consideration of the surgical segment anatomy of the spleen and the surgical techniques presented, organ preservation is possible with high success rates, even in patients with severe splenic damage. In stable patients with minor splenic injury, laparoscopic or conservative treatment can be considered. Splenectomy should be reserved for patients with complete shattering of the spleen or ins-table patients.

Key-Words: traumatic spleen injury - organ preservation - splenectomy

INTRODUCTION

The spleen is the organ most often damaged by blunt abdominal trauma, particularly when it is already pathologically enlarged. Since the early days of trauma surgery, splenectomy has been the standard therapy for traumatic injuries of the spleen for a long time. In recent years however, new findings on the immunological and haematological functions of the spleen have led to an increased emphasis on splenic conservation whenever this is save and feasible. Splenectomy (asplenia) causes an increased risk of severe infections (e.g. pneumococcal infections, pyelonephritis, haemophilus influenzae - and meningococcal infections, hepatitis etc.) and carries the risk of overwhelming post-splenectomy sepsis (OPSI-syndrome), a potentially rapid fatal septicemia. The OPSI-Syndrome is one of the main reasons for the increased emphasis on splenic conservation in current literature, as this is a frequent and acute complication with an incidence of up to 1% after splenectomy, and an associated mortality of 50-70%. Prevention with vaccinations and antibiotics can reduce the risks of OPSI. The tendency to splenic conservation has been supported by new technologies allowing better intraoperative haemostasis, such as improved glue sealants, thermocoagulation and new surgical strategies. Attempts of auto transplantation of splenic tissue into the omentum majus, however, have not been of significant benefit. The immunological competence of the splenic tissue could not be proven. Nonoperative management of splenic ruptures in selected patients has become more popular and frequent due to improved ultrasound technology and a better availability and quality of computer tomography. It does though still imply a certain probability for secondary splenic ruptures, occurring even weeks or months after splenic injury.

Our study presents a large patient collective and compares the splenectomy to the available operative treatment options that focus on organ preservation.

PATIENTS AND METHODS:

The data of all patients who underwent surgery for blunt splenic trauma within a period of 15 years (1995 - 2009) in the department of surgery of the University Hospital in Luebeck was recorded prospectively in a computerised database.
The type of operative treatment was assessed, and an analysis was performed differentiating between the two main groups of organ preservative technique vs. splenectomy. In the group of organ preservative surgery, all cases were analysed regarding the age, gender, diagnosis, severity of the splenic injury, operative technique (including type of resection), intraoperative complications as well as the postoperative course of the patients.

The decision on the surgical treatment strategy depended on the severity-level of the splenic damage, on associated injuries as well as the cardiovascular situation of the patient (figure 1, table 1). The techniques used for organ preservation were thermocoagulation, suture, glue sealant, splenorrhaphy, net implantation and anatomical partial spleen resection or combination strategies. We are not performing any type of heterotopic autotransplantation of splenic tissue.

RESULTS:
Between 1994 and 2008, 214 patients with splenic trauma were operated on in our hospital. The average age was 45.2 years (15 - 95 years) at the time of the operation. 132 patients of the study group are male (61.7 %) and 82 are female (38.3 %). The spleen could be preserved in 80 of the 214 patients (37.4 %, group 1). Primary splenectomy had to be performed in 62.6 % of the patients (group 2).

The operative technique for organ preservation in group 1 depended on the severity level and localisation of the splenic injury. The spleen could be preserved without partial resection in 73 out of 80 patients in group 1. These patients had an injury of grade 2 to 3 (Moore Spleen Injury Scale). In seven patients with a grade 4 splenic injury, partial resection of the spleen had to be performed.

Organ preservation was mostly performed by using glue sealant (figure 2) in 76.3 % of the cases of group 1 (61 patients), followed by suture in 12.5 % (10 patients) and partial resection of the spleen in 8.75 % of the patients in this group (7 patients). Coagulation was used in 6 cases (7.5 %) (figure 3) and splenorrhaphy with the implantation of a vicryl net in 1 patient (1.25 %) with a grade 4 injury. A combination of some of these techniques was performed in five patients (6.3 %). Table 2 offers an overview on the techniques applied for organ preservation.

Eight of the patients in group 1 (10 %) could be treated laparoscopically. Three of these patients had grade 2 injuries treated by glue sealant, four patients showed grade 3 ruptures, which were also treated by glue sealant in 3 cases and a combination of glue sealant and suture in 1 case and 1 patient had a grade 4 injury managed by a partial resection.

A revision operation had to be performed in four patients (5 %) due to postoperative bleeding. Two of them could be treated by application of glue sealant. Secondary splenectomy had to be performed in the other couple (2.5 %).

A 91 years old female patient whose spleen was preserved by application of glue sealant after a grade 2 splenic rupture died of cardiac failure several days after the operation.

DISCUSSION:
The spleen plays haematological as well as immunological roles. In the adult, it is responsible for the creation, storage and filtration of blood cells, also affecting...
both the cell-mediated and the humeral immunity. Spleenectomy leads to increased risks of severe infections and carries the risk of overwhelming post-splenectomy sepsis. Following splenectomy, the platelet count may rise, leading to an increased risk of clot formation and death\(^7,8\). Because of the spleen’s functions in the cell-mediated and humeral immunity, splenectomy leads to disorders in the immunological response\(^1,9\). One of the severest complications after splenectomy is the OPSI-Syndrome, a potentially fatal septicemia. It is caused by Streptococcus pneumoniae in 50% of the cases \(^10\). The risk for sepsis is 50 times higher in patients with asplenia compared to the normal population. This increased probability of overwhelming sepsis stays life long\(^11\). To minimize the risk of overwhelming sepsis, patients should be immunised against Streptococcus pneumoniae.

Evaluating the complications of asplenia, the risks of organ preservative surgery have to be taken into account as well. Relevant aspects here are e.g. the possibility of infection from blood transfusions and high rates of secondary haemorrhage of up to 3%\(^1,2\).

Knowledge of the segment anatomy of the spleen is the basis for successful organ preservative surgery. The organ’s segment anatomy has been visualised in several studies\(^13,14\). Besides traumatic injury of the spleen, iatrogenic injury makes up to 25% of splenic injuries\(^15\). Attempts of organ preservation certainly play a major role here when the spleen is not entirely shattered (grade 5 injury). To avoid the complications of asplenia, at least about 30% of the splenic tissue has to be preserved\(^3\). Several different surgical techniques and treatment options are known for the operative salvage of the spleen and have to be individually chosen regarding the type and severity of the splenic injury as well as the patient’s situation (figure 1, table 1). Subcapsular haematoma covering less than 10% of the spleen’s surface and capsular tears of less than 1 cm in depth (grade 1) can mostly be treated without an operation. In some cases, it might though be indicated to operate to perform haemostasis e.g. by applying glue sealant. In larger subcapsular haematoma or bleeding tears of the capsule (grade 2), an operation is usually necessary to reach sufficient haemostasis. Coagulation is commonly performed by application of an argon-beam, infrared or hot air\(^16\). In addition, the defect can be sealed (fibrin glue, collagen fleeces etc.). In case of a grade 3 injury, when the subcapsular haematoma covers over 50% of the spleen’s surface or deep tears are present, the spleen can additionally be sutured or wrapped in a haemostatic mesh to ensure proper haemostasis\(^17\). Ruptured haematomas within the parenchyma or avulsions of major vessels (grade 4) usually desire ligation of the injured vessel and partial resection of the traumatised and devascularised tissue. The resection can be performed using different techniques such as the "finger-fracture-technique", ultrasound- or water dissection, or using a laser. In cases of complete shattering with avulsion of the spleen

<table>
<thead>
<tr>
<th>Grade</th>
<th>Splenic injury</th>
<th>Therapeutical options</th>
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<tbody>
<tr>
<td>Grade 1</td>
<td>subcapsular haematoma &lt;10%, capsular tears of less than 1 cm in depth (not bleeding)</td>
<td>conservative treatment</td>
</tr>
<tr>
<td>Grade 2</td>
<td>subcapsular haematoma 10-50%, bleeding capsular tears, intraparenchymal haematoma &lt;2 cm</td>
<td>coagulation, fibrin glue, collagen fleeces, conservative treatment</td>
</tr>
<tr>
<td>Grade 3a/b</td>
<td>subcapsular haematoma &gt;50%, ruptured subcapsular haematoma, bleeding capsular tears &gt;3 cm in depth, intraparenchymal haematoma &gt;2 cm</td>
<td>coagulation, fibrin glue, collagen fleeces, suture, haemostatic mesh/net implantation, partial resection</td>
</tr>
<tr>
<td>Grade 4</td>
<td>ruptured intraparenchymal haematoma, involvement of major vessels</td>
<td>partial resection, haemostatic mesh, splenectomy</td>
</tr>
<tr>
<td>Grade 5</td>
<td>complete devascularisation or fragmentation of the spleen</td>
<td>splenectomy</td>
</tr>
</tbody>
</table>

**TABLE 2**

**TECHNIQUES USED FOR ORGAN PRESERVATION, PATIENT NUMBERS AND PERCENTAGES**

<table>
<thead>
<tr>
<th>Surgical technique</th>
<th>Patient no/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>fibrin glue or collagen fleeces</td>
<td>61/76.25%</td>
</tr>
<tr>
<td>suture</td>
<td>10/12.5%</td>
</tr>
<tr>
<td>coagulation</td>
<td>6/7.5%</td>
</tr>
<tr>
<td>partial resection of the spleen</td>
<td>7/8.75%</td>
</tr>
<tr>
<td>net implantation, haemostatic mech</td>
<td>1/1.25%</td>
</tr>
<tr>
<td>combination of different techniques</td>
<td>5/6.25%</td>
</tr>
</tbody>
</table>
from its pedicle (grade 5), splenectomy has to be performed\textsuperscript{18}. Another controversial therapeutical option is the auto-transplantation of splenic tissue into the peritoneal cavity. As long-term results are questionable, it should only be performed if organ preservation is impossible or failed anyway.

In recent years, there has been an increasing tendency to avoid unnecessary operations in trauma patients with minor splenic injury. Factors such as the mechanism of trauma, the severity of the splenic damage, further injuries and conditions as well as the patient’s age and level of comorbidity play important roles in the evaluation of the situation, arguing for or against a laparotomy. A non-operative therapy is possible especially in young and stable patients with isolated splenic trauma. When the decision for a non-operative therapy has been made, the patient needs proper monitoring for at least one to two weeks, as subcapsular haematoma can cause delayed rupture. Furthermore, it must be possible to perform a laparotomy at any time if necessary. Organ preservation should also be the aim in secondary operations. The success rate here is about 50\%\textsuperscript{19,20,21}.

Another possibility of non-operative therapy is splenic artery embolization (SAE). SAE has been used in both stable responders and transient responders for fluid resuscitation. However, such treatment requires intimate cooperation between the trauma surgeon and the interventional radiologist and a constant supervision by a surgeon with an operating room on standby. Not all hospitals will have the proper facilities for such treatment. Furthermore, infarcts are common after splenic embolization, which might lead to abscess within the organ\textsuperscript{22}.

Considering the surgical segment anatomy of the spleen, organ preservative surgery is possible even in high-grade splenic injury and with good results. Intraoperatively, all possible techniques should be taken into account and applied according to the pattern of injuries. In stable patients, minor lesions in favourable locations can even be treated laparoscopically. Splenectomy should be preserved for cases with complete shattering of the spleen or acutely life-threatening situations with highly instable patients.

**SUMMARY**

**ULOGA PREZERVACIJE ORGANA KOD HIRURŠKOG LECENJA TRAUMATSKJE LEZIJE SLEZINE**

Uvod: Nova saznanja o imunološkim i hematološkim funkcijama slezine, postoperativnim rizicima posle splenektomije kao i napredak u hirurškoj tehnici uticali su, u poslednjim godinama, na povećan interes za prezervaciju slezine u uslovima njene traumatske lezije. Materijal i metode: Prospektivno su prikupljeni podaci svih pacijenata operisanih zbog traumatske lezije slezine u periodu od 1995. do 2009. godine i analizirani su prema tipu ope-
racije, peroperativnim i postoperativnim komplikacijama i ishodu lečenja. Rezultati: Operisano je 214 pacijenata sa traumatskom lezijom slezine. Slezina je prezervirana kod 80 pacijenata (37,4\%, grupa 1), upotreboj termokoagu-
lacije, suture, fibrinskog lepka, splenorafije i parcijalne resekcije ili ko-mbinovanjem tehnika. Reintervencija je bila neophodna kod 4 pacijenata (5 \%), od toga je kod 2 pacijenata slezina prezervirana aplikacijom fibrinskog lep-ka. Osam pacijenata iz grupe 1 je lečeno laparoskopskim putem (10 \%). Zaključak: Poznavanjem segmentne anatomi slezine i primenom pomenuih hirurških tehnika, prezervacija slezine moguća je u visokom procentu čak i kod pacijenata sa teškom traumom slezine. Kod stabilnih pacijenata sa minimalnom lezijom slezine može se razmotriti konzervativni ili laparoskopski pristup u lečenju. Splenektomija ostaje rezervisana za nestabilne pacijente kao i kod pacijenata sa kompletnom destrukcijom organsa.

Ključne reči: traumatska lezija slezine, prezervacija organsa, splenektomija

**FIGURE 2:** 
HAEMOSTASIS IN A GRADE 2 SPLENIC INJURY USING COLLAGEN FLEECE AND GLUE SEALANT (LAPAROSCOPICALLY)

**FIG. 3:**
THE OPERATIVE TREATMENT OF A Traumatic RUPTURE OF THE SPLEEN PERFORMING PARTIAL SPLENECTOMY
REFERENCES