

特別講演

SPLENECTOMY, SPLENORRHAPHY AND TRANSPLANTATION SPLENOSIS

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INTRODUCTIONS

The spleen is more important than has been realized in the past. Its functions include, the selective scavenging of abnormal and aging cells, cell fragments such as platelets, and various foreign particles such as parasites and other micro organisms. It has the ability not merely to phagocytosize but to process foreign particles by coating them with complement and other immune adjuvants that accelerate their destruction/expulsion by other reticular endothelial cells such as those in the liver (Table I).

Emphasis has been placed properly on the enormous susceptibility of asplenic infants and children to overwhelming sepsis. A milestone in the developing awareness of the clinical consequences of splenectomy in children was the report of 5 deaths in 100 splenectomized children by King and Schumacker in 1952<sup>1)</sup>. King H, Schumacker HB, Jr. : Splenic studies : I. Susceptibility to infection after splenectomy performed in infancy. Catastrophic, fatal, infections with *S. pneumococci* may develop in less than 12 hours. OPSI-Overwhelming Post Splenectomy Infection has a mortality of 70 to 80% (Table II). The danger of OPSI is highest immediately after splenectomy but never returns to normal. Fortunately, asplenic patients retain some antibody response to antigens administered parenterally. The immunization of asplenic patients with polyvalent poly-saccharide vaccine (types 1, 3, 6, 7, 14, 18, 19, 23) against pneumococcus pneumonia is widely accepted. No cases of pneumonia were observed in 96 vaccinated asplenic patients with sickle-cell anemia followed for two years<sup>2)</sup>. In contrast 106 age-matched unimmun-

Table II Death After Splenectomy  
 —children—

Age & No	Interval-months	Organism
1	1	Pneumococcus
3(2)	7, 16	Pneumococcus
6(2)	10, 29	
7	24	H. influenzae
8(2)	12, 36	(1) Streptococcus
10	15	
11(4)	1, 15, 32, 36	(1) Streptococcus
12-15(3)	1, 14, 24, 26	(1) Meningococcus

Table I Functions of the spleen

Hematopoiesis	Culling and pitting
Phagocytosis	Filtering
Cell reservoir	Hormones and factors
Erythrocytes-destruction-platelets	
IgG ↑ -Immunology-IgM ↓	
IgG ↓ (liver) IgM ↑	

ized patients with sickle cell disease developed eight *S. Pneumoniae* infections in the same period. Currently a 14-valent vaccine (Merck, Sharp & Dohme) is available. We immunize patients before elective splenectomy and wait 5 days after emergency splenectomy before vaccinating them and repeat the vaccination in 3 months.

Experimental evidence in mice<sup>3)</sup> suggests a significant decrease in the antibody response of the asplenic animal. Vaccines administered before splenectomy conferred a much greater immunologic protection.

This report concerns splenectomy, splenorrhaphy and splenosis in the adult. The risk of fatal infection is not great in such persons. For example, there was only 2 cases of fatal sepsis in about 1000 person-years of study in a small town, Rochester, Minnesota<sup>4)</sup>. There was an increased danger in patients whose splenectomy was performed in association with various malignant diseases. The specific conditions requiring splenectomy, i. e.: aplastic anemia, thalassemia, malignancies especially lymphomas; all increase the risk of fatal infections. An attack rate of OPSI of 4.3% in 2,795 patients was reported by Singer<sup>5)</sup>.

There is additional clinical evidence of the contribution of the spleen to our immunological defenses. Almost all serious infections with *Babesia* a parasite of erythrocytes has been reported in asplenic persons<sup>6)</sup>. Infections with the "DF-2 organism M" from dog bites and scratches usually develops only in asplenic persons. The recent epidemic of AIDS (associated immunodeficiency syndrome) has been fatal in a number of asplenic individuals; a majority of these patients have been homosexual or have had severe sickle cell anemia.

This relative importance of the spleen in the adult must be kept in mind when one considers the risks of splenorrhaphy, segmental resection of the spleen, splenic artery ligation, or transplantation of splenic fragments. (Induced splenosis). The risk of subsequent hemorrhage associated with any sort of repair must be weighed against the immediate and life long risks of immediate splenectomy. Conti has advocated ligation of the splenic artery of injured spleens with preservation of its collateral blood supply (short gastric and left gastroepiploic anastomosis inferiorly and inferior diaphragmatic superiorly). This collateral blood supply has been judged adequate to sustain the viability of the spleen in 94% of the specimens<sup>7)</sup>. The effects of splenic artery ligation on spleen viability have been determined in various animal species. Canine spleens show negligible gross and histologic changes<sup>8)</sup> and normal isotopic uptake 16 weeks after splenic artery ligation<sup>9)</sup>. In the rabbit, compensatory hypertrophy occurs in the spleen after artery ligation and has a substantial immunological reaction when compared to splenectomized rats<sup>10)</sup>. There is currently no specific correlative data between the experimental results in laboratory animals and the clinical preservation of the immunological reaction in humans following ligation of the splenic artery. Yet, the increasing body of experimental evidence seems to indicate that, from the standpoint of preservation of immunity, ligation of the splenic artery is a better choice than splenectomy as a technique to reduce the hazard of attempts to repair serious injuries involving the central parenchyma of the spleen or lacerations of the terminal branches of the splenic artery.

### INJURIES OF SPLEEN

**Table III** summarizes the operative care of injuries to the spleen since 1977 at the Denver General Hospital. The pattern of serious injuries reflects the kinds of emergency patients admitted to this hospital. Approximately 70% of our patients had blunt injuries, usually in car accidents, 15% had penetrating injuries from stab wounds, 10% had gunshot wounds, and 5% had accidental injuries or therapeutic excisions by surgeons.

The number of iatrogenic injuries to the spleen has decreased sharply as our surgeons in training have become aware of the dangers of splenectomy.

#### 1) Preoperative care :

Denver General Hospital (DGH) is the trauma center for Denver, Colorado and provides emergency transportation via ambulances stationed in different parts of the city. The maximum response time (notification of injury until ambulance arrival on the scene) in five minutes.

Resuscitation at the hospital is continued by a trauma team composed of residents and attending staff

Table III Surgery of The Spleen

Year	Total	Splenectomy	Repairs	Implants
1977	30	28	2	—
1978	35	24	11	4
1979	27	19	8	4
1980	32	18	18	9
1981	34	11	23	8
1982	35	15*	20+*2	13

\* 2 failures of splenorrhaphy

from the Departments of Surgery and Emergency Medicine. Crystalloid resuscitation is carried out via large bore central venous catheters, upper extremity. Type specific blood is used when feasible; low titer O negative blood is reserved for the patient in extremis. Thoracotomy with temporary crossclamping of the aorta is employed in patients with cardiac standstill but manifesting other signs of life (pupil reactivity, respiratory effort, or motor activity).

### 2) Diagnostic procedures and Indication for Surgery :

Patients with overt peritoneal signs are explored promptly. Stab wounds to the abdomen, are managed selectively based on local wound exploration, and diagnostic peritoneal lavage. The decision to perform laparotomy for blunt trauma is also frequently determined by peritoneal lavage through a catheter placed just below the umbilicus. The specific indications for abdominal exploration following a stab wound or blunt injury are : 1) aspiration of more than 10 cc of gross blood, 2) lavage fluid flowing from the bladder catheter or chest tube, and 3) lavage effluent with more than 100,000 red blood cells/mm<sup>3</sup>, or more than 500 white blood cells/mm<sup>3</sup>, or an elevated amylase or alkaline phosphatase levels.

Preoperative antibiotics are administered to all patients undergoing laparotomy for trauma. For blunt injuries a first generation cephalosporin is given, whereas for penetrating injuries of the bowel a broad spectrum regimen (ampicillin, amikacin sulphate, and clindamycin) is used. Antibiotics are stopped after two postoperative doses except in patients with penetration of the distal small bowel and colon.

### 3) Operative procedures :

Rapid exploration of the abdomen is performed through a midline incision. The first priority is control of hemorrhage followed by systematic examination of the viscera and the entire large and small bowel for perforations. In this group of patients with injuries to the spleen approximately 50% had injuries to other organs and about a third of them had some contamination by gastrointestinal contents. Small lacerations of the liver and spleen are often controlled by packing until all of the injuries are identified.

#### (a) Splenectomy :

Uncontrollable hemorrhage from the spleen or its vessels subsequent to temporary proximal clamping of the splenic artery must be treated by immediate splenectomy.

The spleen is an organ almost entirely surrounded by peritoneum which is firmly adherent to its capsule. Layers of the greater omentum intervene between the spleen and the stomach and contain the gastroepiploic and brevis branches to the spleen. The lienorenal ligament is formed where the wall of the general peritoneal cavity contacts the omental bursa between the left kidney and spleen. The splenic vessels pass between its two layers as they leave the superior border of the pancreas to enter the hilum of the spleen. The superior prolongation of this ligament attaches the spleen to the diaphragm and is known as the phrenocolic ligament. Its inferior prolongation is known as the lienocolic ligament and attaches the spleen to the proximal descending colon.

We first divide any filmy attachments to the capsule and the individual vessels within the so-called ligaments just described. The major maneuver is the division of the lienorenal ligament together with its cephalic and caudad prolongations. This allows delivery of the spleen into the operative field for

inspection and repair. The terminal splenic vessels—these-called “crow’s foot” of the splenic artery-, are exposed at the hilus by severing the anterior layer of fascia. The vascularity of the spleen is very variable as is beautifully illustrated by Nicholas Michel in his “Blood Supply and Anatomy of the Upper Abdominal Organs with Descriptive Atlas” (Figs. 1 and 2)<sup>11)</sup>.

(b) Hemostasis and splenorhaphy :

Small capsular tears of the spleen at the site of fascial or vascular attachments are controlled by the application of microfibrillar collagen (Avitene), and less frequently by electrocoagulation.

Fig 1

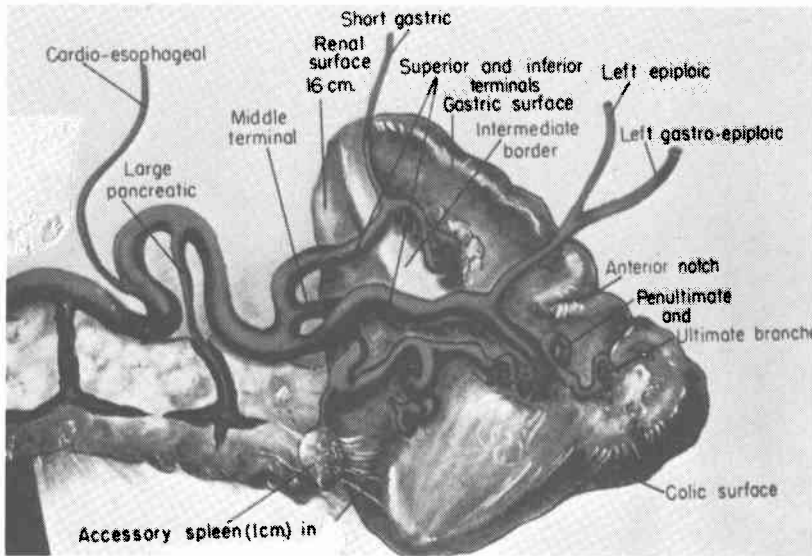
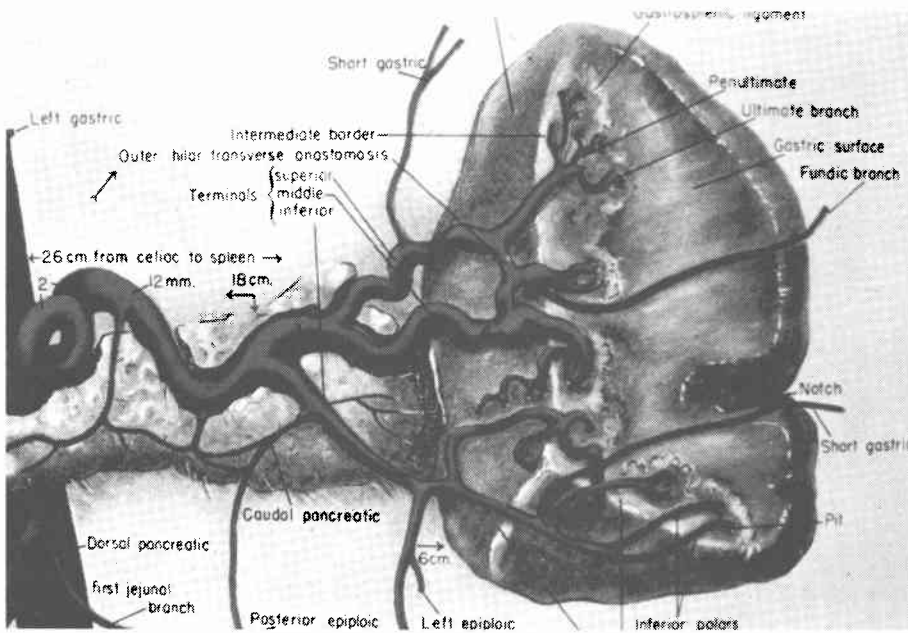


Fig 2



Electrocoagulation is never used for hemorrhage from the stroma of the spleen. Lacerations are approximated by horizontal mattress stitches with absorbable polyglycolic sutures through 4 mm wide Teflon plegets (Figs. 3 and 4).

When either the superior or inferior poles are lacerated, segmental resections are performed after ligation of the segmental artery at the hilus. In a few minutes the demarcation line can be seen. However, in one of our patients there was an intersegmental artery within the spleen that was not adequately controlled, it hemorrhaged 24 hours later, and the spleen had to be excised. The most dangerous lacera-

Fig 3

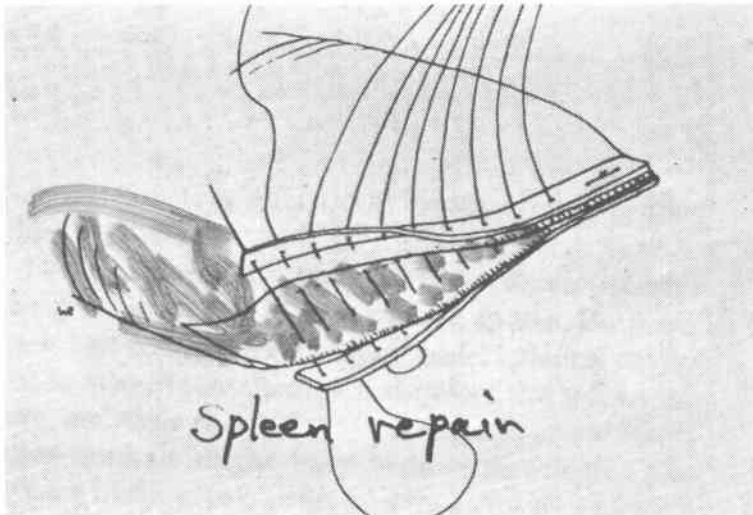


Fig 4 Repair of laceration : Teflon plegets were placed on the surface of injured spleen through which several mattress stitches were done.



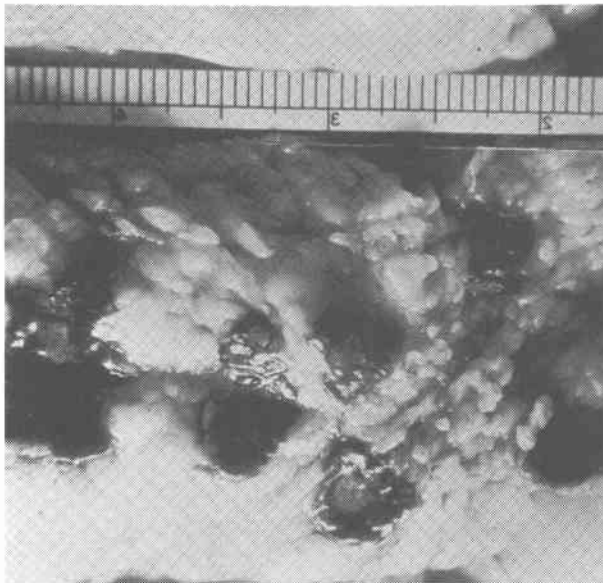
tions are longitudinal ones near the hilus ; these should not be repaired. Nylon nets much like hair nets have been proposed as a technique for use in children with shallow lacerations (Fig. 5). It is doubtful that this method will be used much in adults since the capsule is relatively thin and the spleen doesn't contract very much.

Once hemorrhage is controlled any excessive foreign material such as collagen and Surgicel is removed to reduce the danger of infection.

Fig 5 Wrapped in jured spleen with Nylon nets.



Fig 6 Spleen transplantation I : Small pieces of spleen slices were implanted on the omentum.



The spleen and omentum are replaced in the upper left quadrant without drainage. The abdomen is usually washed with several liters of warm saline. Drainage catheters are used with laceration of the liver for the detection of bile but are inadequate for the early detection of hemorrhage. If there is any evidence of injury to the pancreas, drainage is used. The use of CAT scans for the detection of collections of fluid at the spleen-site are helpful, but rarely necessary. Diagnostic ultra sound is also useful.

We have not used permanent ligation of the splenic artery with retention of spleen.

(c) Spleen transplantation :

We have performed 35 implants of 5 slices of spleen into pouches of omentum after splenectomy. In early cases the slices measured only  $20 \times 20 \times 5$ mm (Fig. 6) but subsequently we have used 5 slices

Fig 7 Spleen transplantation II.

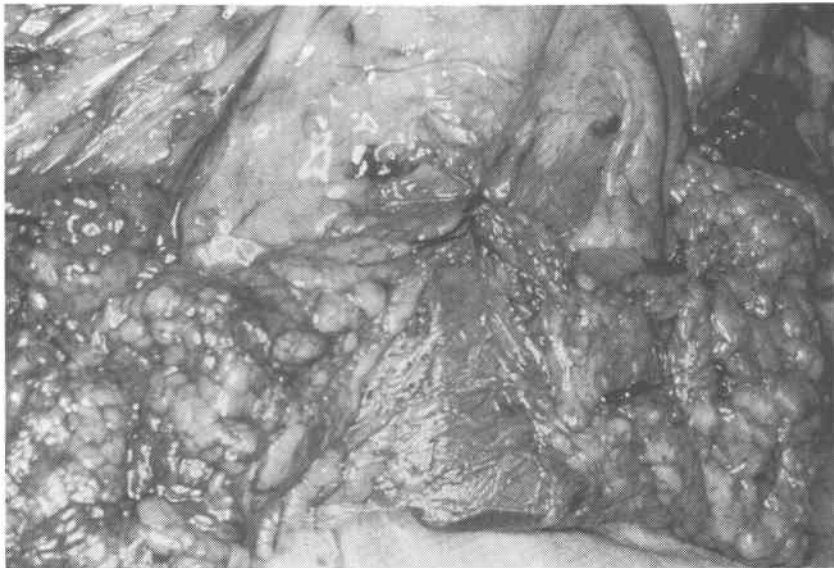
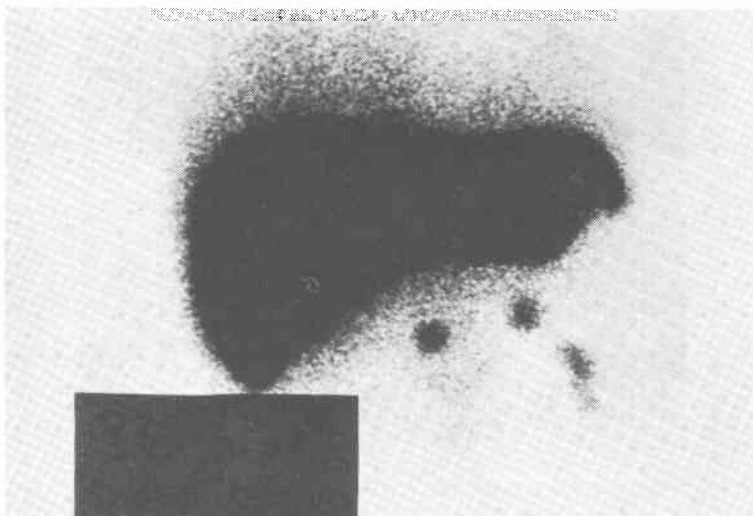


Fig 8 Scans of liver and transplanted spleens.



measuring  $40 \times 40 \times 5$ mm (Fig. 6). Evidence of the vascularization of these implants has been obtained by scans with radioactive Technetium-99 sulfur colloid. The scans performed at 6 months were all positive (Fig. 8)<sup>12</sup>. Platelet counts and levels of IgM were within normal limits. Determinations of erythrocyte pitting have not been done to date<sup>13</sup>.

### COMPLICATIONS

No patients have died as a result of splenorrhaphy or implantation. Ten patients died as a result of associated injuries within a few days.

One patient died 20 days after operation from peritonitis and intraabdominal abscesses; there had been multiple bowel perforations. The sites of spleen implants in this patient were infected; their role in maintaining the infection could not be determined. More importantly a 61 old lady with small implants died of overwhelming infection with *S. pneumococcus* about 5 months after operation. This patient had a long history of alcoholism and severe cirrhosis of liver. Autopsy examination revealed the 5 ( $20 \times 20 \times 3$ mm) spleen implants were unchanged in size, viable, but they were not heavily populated with lymphocytes.

Two patients with splenorrhaphy have had immediate complications. In one instance the patient was given aspirin "because of the high platelet count". This patient also had a jejunal resection and developed an infected hematoma that required drainage and subsequent resection of the residual spleen<sup>14</sup>.

The second patient had a segmental resection plus repair of additional lacerations. A slow persistent postoperative hemorrhage was detected, the spleen resected, and spleen slices implanted.

### DISCUSSION

Ever since Assolant in 1802 proved the feasibility of segmental resection of the spleen in dogs, investigators in France, Germany and South America sought confirmation of the segmental distribution of the internal blood supply of the spleen. It was Pean, the great Paris surgeon of the last century who in 1867 first performed a segmental splenectomy when he resected a portion of the spleen containing a cyst, by segmental ligation of the branches of the splenic artery<sup>15</sup>.

Through the 1950's, Marcelo Campos Christo<sup>16</sup> Professor of Surgery at the University of Minas-Gerais in Brazil, began the quest for laboratory confirmation of the anatomical division of the spleen into segments similar to that found in the lung<sup>17</sup>, liver<sup>18</sup> and Kidney<sup>19</sup>. He performed a series of partial splenectomies in a group of 34 dogs after segmental ligation of the terminal splenic artery branches and subsequently followed this work with careful cannulation and injection of plastic vinylite into the terminal segmental arteries of 40 human spleens obtained at operation or necropsy. Forty percent of the forty spleens injected with vinylite had four anatomical segments; another 40% had three segments; 12.5% had two segments and 7.5% had five segments. All segments had independent blood supply and were separated from one another by relatively avascular planes. To obtain further corroboration, Campos-Christo injected another eleven human spleens with mercury-oxide through the cannulated terminal branches of the splenic artery.

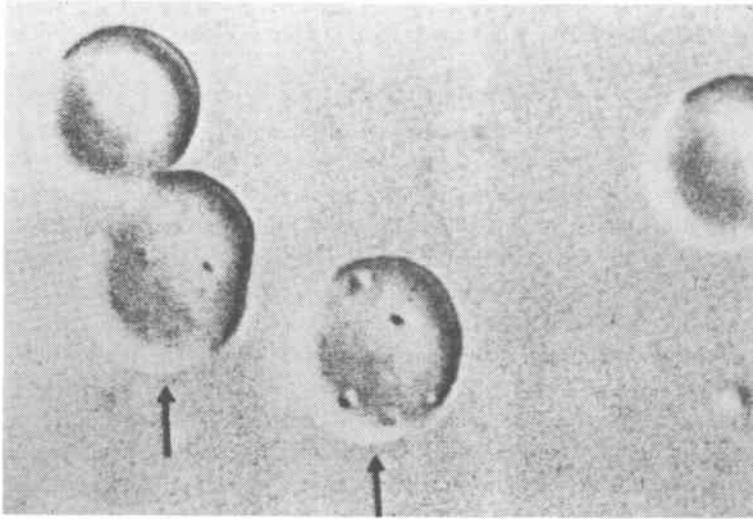
Immediate X-ray confirmed likewise the separation of segments. In 1959 he published the first three cases of "systematized" partial splenectomy in the human<sup>20</sup> and in 1962 he published a total of eight partial splenectomies with one mortality due to an overlooked bullet wound of the stomach<sup>21</sup>.

Splenorrhaphy should not be done unless it can be done safely. O'Neil and McDonald<sup>22</sup> reported serious sepsis in 2% of asplenic patients with an average followup of only 4 years. Others have noted that 50% of all deaths from sepsis following splenectomy have been in adults. These rates of sepsis and death after splenectomy are magnified by the inclusion of patients with malignancy especially Hodgkins disease and lymphomas which have additional severe immune deficiencies. Splenectomy mortality for Hodgkin's disease in children is 5%<sup>23</sup>, for aplastic anemia 7.5%. The much lower attack rate in a splenic persons reported by Schwartz et al<sup>24</sup> probably reflects a more accurate attack rate in the general population.

We are the only surgeons who have reported complications associated with splenorrhaphy and spleen implants. Pachter et al<sup>25</sup> and Giuliano and Lim<sup>26</sup> reported no complications in a total of 57 patients. The volume of residual spleen in experimental animals required for a normal immune status has estimated to



Fig 9 PiHed and vacuolated erythrocytes.



be at least 25%. The critical volume of a human spleen isn't known and undoubtedly would be dependent the function of the remaining reticulo-endothelial cells in the liver, bone marrow and elsewhere. It is noteworthy that whereas the major function of the spleen involves IgG coated particles, the cells in the liver predominately handle IgM coated particles.

One must have some reservations about the function of spleen implants and therefore, there must be little or no morbidity associated with them. Perhaps more slices of spleen should be implanted. One unpublished study from Europe involves shredding the spleen and inserting it within rolls of omentum. Unfortunately there are no specific, critical assays of splenic functions. One group of investigators are using enumeration of pitted or vacuolated erythrocytes (Fig. 9) and the clearance of isotope-labelled, heat-damaged autologous erythrocytes. Patel et al<sup>27)</sup> reported that four adults with splenectomy and implantation had normalization of IgM and complement levels, and lessening of the number of abnormal erythrocytes with Howell-Jolly bodies.

All patients with splenectomy and implants should be vaccinated.

#### SUMMARY

We are performing an increasing number of splenorrhaphies as our experience increases. The efficacy of spleen implants remain to be determined. The increased interest in preserving the spleen has resulted in the salvage of many spleens with minor injuries. Nearly 100% of all iatrogenic injuries (which constitutes 10 to 20% of all splenectomies<sup>28)29)</sup>, should be salvageable by current techniques.

The value of preserving the spleen in children has been established without much question<sup>30)</sup>.

Acknowledgement : The authors consider this report a merely supplement to the many excellent articles in the Japanese literature on surgery of the spleen and therefore we have not included them.

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