Anat Clin (1982) 4:265–277

ANATOMIA CLINICA

Anatomical Approach to the Vascular Segmentation of the Spleen (Lien) Based on Controlled Experimental Partial Splenectomies

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Summary. The role played by the spleen in the immunological defence against infection is well known. The authors have carried out an anatomical and experimental study on the vascular segmentation of the spleen, on which they base the technique of controlled partial splenectomy. They emphasise that in 300 splenorraphies and partial splenectomies collected in 1979 from the literature by Morgenstein, no case necessitated further surgical intervention for removal of remaining spleen.

Segmentation vasculaire de la rate (lien). Bases anatomiques et expérimentation des splénectomies partielles réglées

Resumé. Le rôle joué par la rate dans la défense immunologique contre l'infection est bien connu. Les auteurs font une étude de la segmentation vasculaire de la rate, anatomique et expérimentale, à partir de laquelle est décrite la technique d'une splénectomie partielle réglée. Ils rappellent que sur 300 splénorraphies et splénectomies partielles colligées en 1979 dans la littérature par Morgenstein, aucune réintervention pour complément d'exérèse n'est signalée.

Key words: Spleen, vascular segmentation – Partial splenectomy – Splenorraphy – Splenic injury – Splenic surgery

Many publications, both clinical and fundamental, have in the last two decades confirmed the primordial role of the spleen (lien) in the immunological defence of the organism against infection [2, 13, 14, 17, 20, 22, 27, 29, 30, 31, 39, 49, 50, 54, 55, 56]. Some voices of authority have been raised against the unnecessary removal of this organ which is not considered, classically, as essential for life. The principle of conservative splenic surgery is nowadays considered important not only in the young child but also in the adult [11, 38, 49] and even then, not only following trauma but also in several other afflictions (benign tumour, haematological illness, staging in Hodgkin's disease, iatrogenic damage to the spleen during surgery in the supra-mesocolic region...). When considering conservative treatment, controlled partial splenectomy, hitherto considered as a heresy in the same way as splenorraphy, is proving to be of increasing interest to surgeons, technical progress providing more and more reliable haemostatis.

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Anatomical Basis

Vascular Segmentation of the Spleen

Ever since Assolant (1802), all authors agree in insisting upon the terminal character of the splenic arterial supply, each artery penetrating the hilum supplies a parenchymal "department" which is absolutely independent of its neighbour.

To the best of our knowledge, the first study of a truly surgical character was that carried out in the Cordier Laboratory of Anatomy in Paris between 1950 and 1952 and which we presented at the 39th Congress of the Association of Anatomistes in April 1952 [41a]. At that time the plastic media for injection had only just been introduced into the method of corrosion, and the concept of controlled segmental resections were very popular (lung, liver, kidney).

This work on the intraparenchymal arrangement of the splenic blood supply showed that the spleen (lien) was composed of autonomous vascular segments corresponding to the penetrating ar-

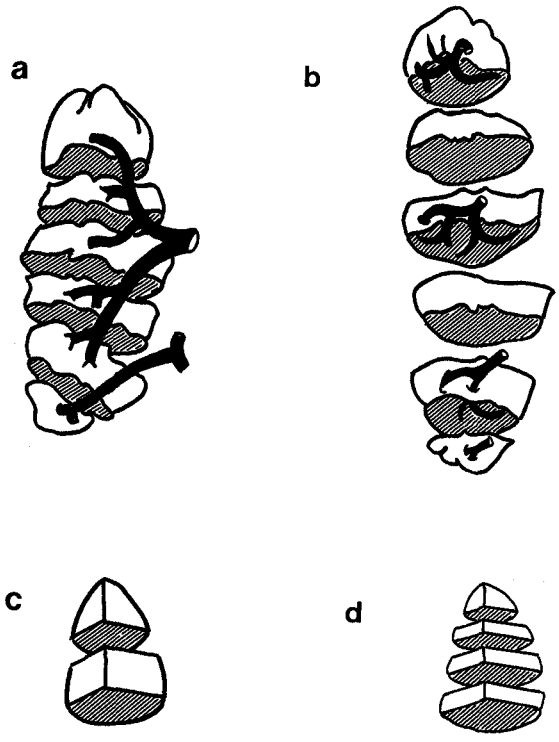

Fig. 1
Arterial segmentation of the spleen (Nguyen Huu 1952). **a** The arterial segments of the spleen with their penetrating arteries. **b** Arrangement similar to a pile of plates. **c** Diagram of the upper and lower hemispleens. **d** Diagram of the arterial segments

Segmentation artérielle de la rate (Nguyen Huu 1952) **a** Les segments artériels de la rate avec leurs artères pénétrantes. **b** Disposition en pile d'assiettes ou en broche d'abattis. **c** Diagramme des deux hémirates supérieure et inférieure. **d** Diagramme des segments artériels

teries which one may approach and tie off at the hilum of the organ (hilus lienis). These segments are superposed perpendicularly one upon the other along the principal axis of the organ rather like a pile of plates or meat on a skewer. The segments have also clearly separated from each other by intersegmental planes which are avascular or poorly vascularised, and serve to divide the splenic parenchyma into individual slices (Figs. 1 and 2).

The rare and minuscule arterial or venous anastomoses – visible in angiographies or on casts – are practically negligible, which once more confirms the terminal character of these vessels which penetrate the spleen at the level of its hilum (hilus lienis).

Simionescu et al. [53] from Bucharest who were entirely familiar with our studies, applied the name lobes (lobus) to these hemispleens: a superior lobe (lobus lienalis superior) and an inferior lobe (lobus lienalis inferior) each composed of two segments; a polar (segmentum polaris) and a mesosplenic (segmentum mesolienale) segment. Like ourselves, they described the interlobar, poorly vascularised, intersegmental planes orientated transversely. On the other hand, they believed that while the arteries were terminal, the "veins are arranged in a single network (with broad anastomoses) situated in the interior of the organ" [53] (Fig. 3).

Cayotte et al. [10] from Nancy looked in some detail at "the vascular organisation of the spleen" in 1970. It should be noted, for the purposes of the problem in hand, that in 90% of cases, the splenic artery (a. lienalis) bifurcates in order to supply the two hemispleens which we described in 1952, and that in the remaining 10% of cases, it gives three branches (20% according to Michels [33]), the intermediate being a middle terminal rather than superior polar branch as Lipshutz has suggested. Like Simionescu, they divide the spleen into two lobes, each comprising two segments (lobes and segments being supplied respectively by the primary and secondary branches of the splenic artery):

– superior polar and superior mesosplenic segments for the superior lobe,
– inferior mesosplenic and inferior polar segments for the inferior lobe (Fig. 4).

In cases of trifurcation of the splenic artery, the 3rd intermediary segment is to be found more or less attached to the superior lobe. Moreover "the authenticity of this 3rd branch is questionable because in reality it may consist of a terminal bifurcation of one or either of the two classical branches" [10].

Tertiary branches may also reach the hilum independently and supply the "thinner areas". A penetrating mesosplenic artery may also sometimes send a branch to the sub or supra-adjacent territory, which modifies the classical segmental concept and enabled Cayotte et al. [10] to describe four types; in the extreme, the plane of cleavage would be longitudinal rather than transverse, dividing the mesospleen into "anterior and posterior" halves (type D; Fig. 4).

More recently (1976) Gupta et al. [25] from Agra (India), after agreeing that "Dreyer and Budtz-Olson are widely considered to be the first to have described the segments of the spleen[1]", found a bifurcation in 84% and a trifurcation in 16% of the splenic arteries studied, supplying either "2 or 3 segments" in each spleen. They also

1 In the work of Dreyer and Budtz-Olson on splenic phlebography, a paragraph of three lines draws attention to the terminal character of the splenic veins. (Dreyer B and Budtz-Olson (1952) Splenic venography. Lancet (March) pp 530–531.

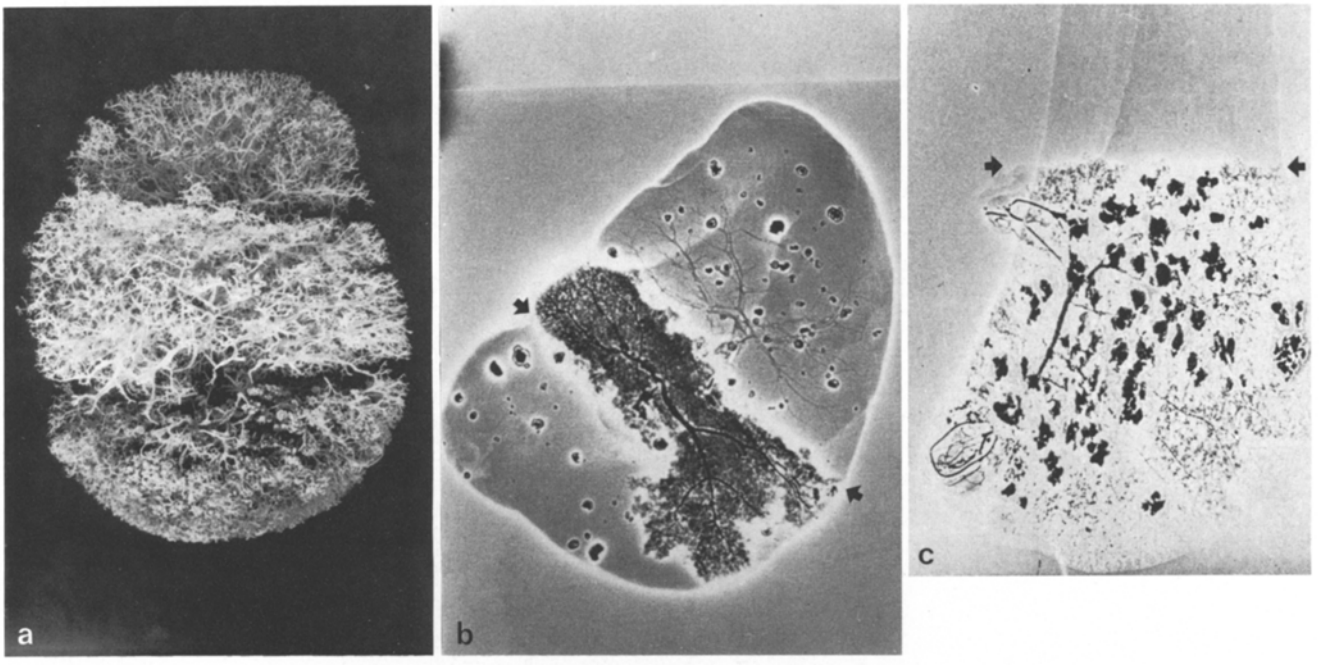

Fig. 2
Vascular segmentation of the spleen (lien). **a** and **b** Human spleen: **a** a cast of a corrosion-injection of three groups of segments; **b** xerograph following injection of lipiodol into a penetrating artery (Prof. Bellet). **c** Dog spleen: xerograph following injection of lipiodol into the artery of the centro-caudal pole (Prof. Bellet). Note the segments and the clarity of the intersegmental boundaries (*arrows*)

Segmentation vasculaire de la rate (lien). **a** et **b** Rate humaine. **a** Cast d'injection-corrosion de trois groupes de segments; **b** xérographie après injection de lipiodol dans une artère pénétrante (Pr Bellet). **c** Rate canine: xérographie après injection de lipiodol dans l'artère du pôle ventro-caudal (Pr Bellet). Remarquer les segments et la netteté des limites intersegmentaires (*flèches*)

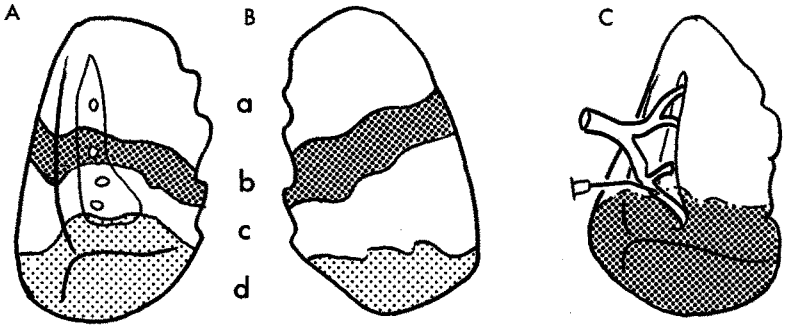

Fig. 3
Simionescu et al. [53]. **A** and **B** Two lobes, four segments. *Segments: a* superior polar; *b* superior mesosplenic; *c* inferior mesosplenic; *d* inferior polar. **C** Investigation of the intersegmental plane by injection with methylene blue

Simionescu et al. [53]. **A** and **B** Deux lobes, quatre segments. *Segments: a* polaire supérieur; *b* mésoliénal supérieur; *c* mésoliénal inférieur; *d* polaire inférieur. **C** Recherche du plan intersegmentaire par injection de bleu de méthylène

recall that other authors have found such segments in a certain number of species [25].

Splenic Pedicle (radix lienis)

As partial splenectomy depends largely upon dissection and primary ligature of the vessels which penetrate and supply these segments, it seems worthwhile to recall their different arrangements.

Without discussing in detail the views of diverse authors which may be easily found in Cayotte's article [10], we will emphasise the following important principals:

a) The splenic artery (Arteria lienalis) and its branches reach the splenic hilum by running in the lienorenal ligament (lig. phrenicolienale) which may be easily approached by opening the omental bursa after sectioning the gastro-splenic ligament (lig. gastrolienale) and the short gastric vessels (v. gastricae breves) which it contains.

b) The point of terminal bifurcation of the splenic artery lying in general between 2 and 6 cm

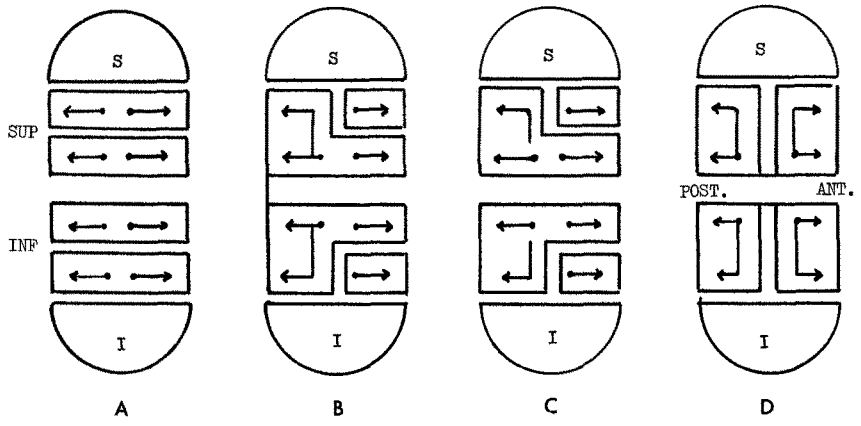

Fig. 4
Diagrammatic arrangement of the territorial blood supply. Superior and inferior lobes; polar segments (*S* and *I*) and mesosplenic (*S* and *I*); the territories with four types (after Cayotte et al. [10])

Disposition schématique de la vascularisation territoriale. Deux lobes supérieur et inférieur; les segments polaires (*S* et *I*) et mésoliénaux (*S* et *I*); les territoires avec quatre types (d'après Cayotte et al. [10])

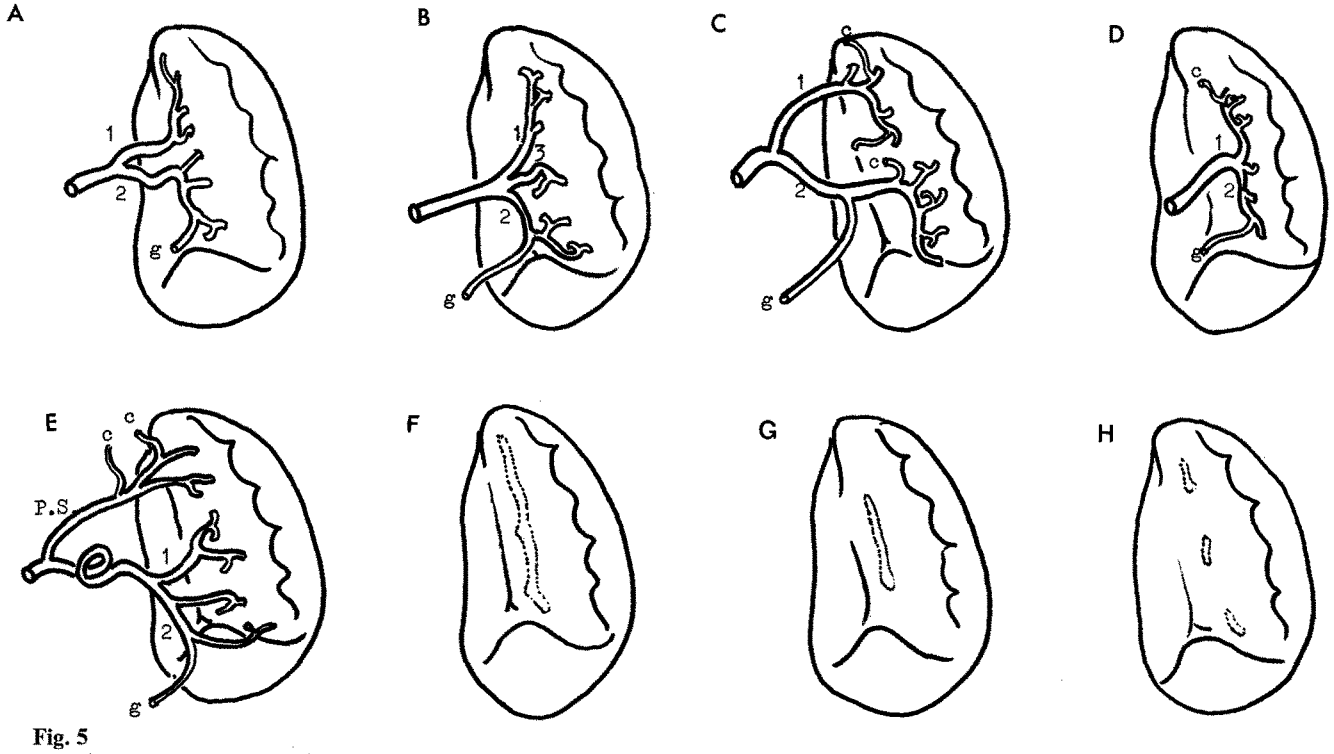

Fig. 5
Splenic pedicles. **A–E** Surgical types. **A** Bifurcation (*1* and *2*). **B** Trifurcation (*1, 2* and *3*). **C** Long pedicle in the form of a horizontal Y. **D** Short pedicle in the form of a horizontal T. **E** Separate superior polar artery. *g* left gastro-epiploic artery, *c* short gastric arteries, *P.S.* superior polar artery. **F–H** Anatomical types (after Cayotte et al. [10]): spread out (**F**), condensed (**G**), dispersed (**H**)

Pédicules spléniques. **A–E** Types chirurgicaux. **A** Bifurcation (*1* et *2*). **B** Trifurcation (*1, 2* et *3*). **C** Pédicule long en Y couché. **D** Pédicule court en T couché. **E** Polaire supérieure séparée. *g* artère gastro-épiploique gauche, *c* artères gastriques courtes, *P.S.* artère polaire supérieure. **F–H** Types anatomiques (d'après Cayotte et coll. [10]): étalé (**F**), condensé (**G**), dispersé (**H**)

from the hilum (extremes: 1 to 12 cm), it is possible to distinguish two main surgical types of pedicle (Fig. 5):

– the long pedicle forming a horizontal Y is seen where the bifurcation occurs early on, giving off radial segmental branches which are relatively long, easy to isolate and ligature,

– the short pedicle in the form of a horizontal T, occurs where the bifurcation is much later: the splenic artery "runs up against the hilum" [41a] in two terminal branches which course more or less parallel to the hilum, giving off from their lateral surface some very short segmental branches (averaging 1 cm) best described as the "teeth of a comb"; they are much more difficult to get at surgically.

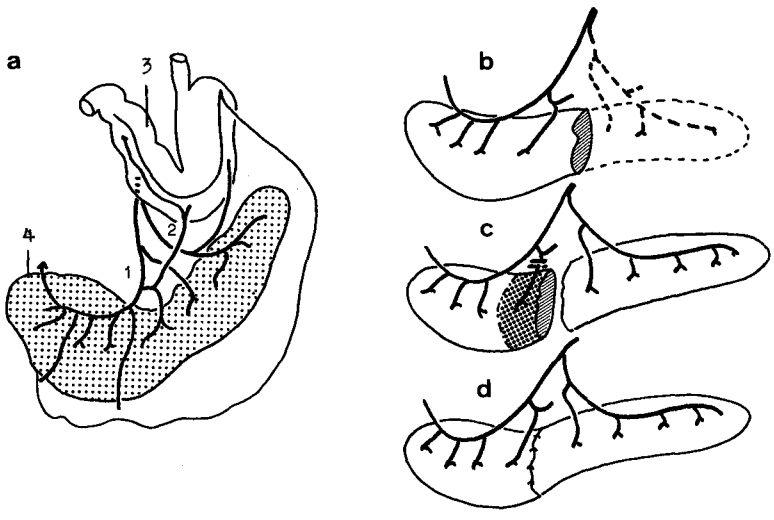

Fig. 6
Experimental splenectomy (Nguyen Huu [41c]). **a** Splenic arteries in the dog. **b** Controlled partial hemisplenectomy. **c–d** Division of the spleen, according to bloodless planes (arterial clamping). *3* stomach, *4* spleen

Splénectomie expérimentale (Nguyen Huu [41c]). **a** Artères de la rate chez le chien. **b** Hémisplénectomie partielle réglée. **c, d** Division de la rate selon le plan exsangue (clampage artériel). *3* estomac, *4* rate

Looked at in a different light, ever since Ssoson-Jaraschewitsch (1927), anatomists have distinguished magistral from distributed types [33].
– *The magistral types,* fortunately rare (23% according to Cayotte et al., 30% according to Michels) correspond to late terminal bifurcation: the penetrating arteries which are large in calibre but few in number group themselves together "in a compact band; the hilum is reduced in size and its length does not even reach half that of the antero-medial surface (facies gastrica) of the spleen of which it occupies the central area" [10]. This is the "condensed type" (Fig. 5).
– In contrast, when the arteries penetrate in several "well separated, distinct hila", the term *distributed* is used, condition much more frequent (70% according to Michels) involving early bifurcation of what are called short splenic arteries.
– Between these two extremes, Cayotte et al. [10] have described a "spread out" type (30%).

It is worth noting that the vascular arrangement is much simpler in children than in adults [10], the arteries found in the pedicle are only represented by primary and secondary divisions of the splenic artery (a. lienalis).

Experimental Basis

The finding, in plastic casts, of segmental vascular areas (differently coloured), of their easy separation thanks to clearly distinguishable intersegmental planes of cleavage, gave us the idea at a time when segmental resections were very much in vogue (lung, liver, kidney), to undertake on the one hand, controlled partial splenectomies, and on the other hand, "bloodless section of the parenchyma" providing an anatomical explanation for certain "dry ruptures" of the spleen.

We have explored experimentally in 20 dogs the many possibilities which arise from the terminal organisation of blood supply of this veritable "sponge of blood" [41a]. In this study which was published in the Presse Médicale in 1956 [41c], we performed: either distal partial splenectomies (polar splenectomy, hemisplenectomy), or segmental resections from the middle of the mesospleen, followed by the suture or otherwise of the two remaining polar segments (Fig. 6).

We showed that the intersegmental so called "bloodless planes" could be located simply by rendering the segmental territories ischaemic (by temporarily clamping or ligaturing the appropriate penetrating artery): the ischaemic zones become violet or even blackish in colour, distinguishing them clearly from the crimson of the rest of the organ.

Section of the parenchyma was carried out perpendicular to the principal axis of the organ "either by means of a lancet or better with a blunt instrument, crushing the splenic pulp in order to extract the tougher network of vessels (a closed pair of curved sissors, a Leriche dissector, the nail of a gloved thumb)" [16].

A similar operative protocol has subsequently been used by several authors, most of them cited our work: Zappala [61], Campos Christo [9] from the Brazilian school of Belo Horizonte, Bourgeon and Mouiel [5], De Boer et al. [16], Morgenstern, Shapiro [38], Wolfgang Ruf et al. [60], Dixon et al. [18].

Simionescu et al. [53] of Bucharest, in the discussion part of their article on the arterial segmentation of the spleen (1960) suggested that the seg-

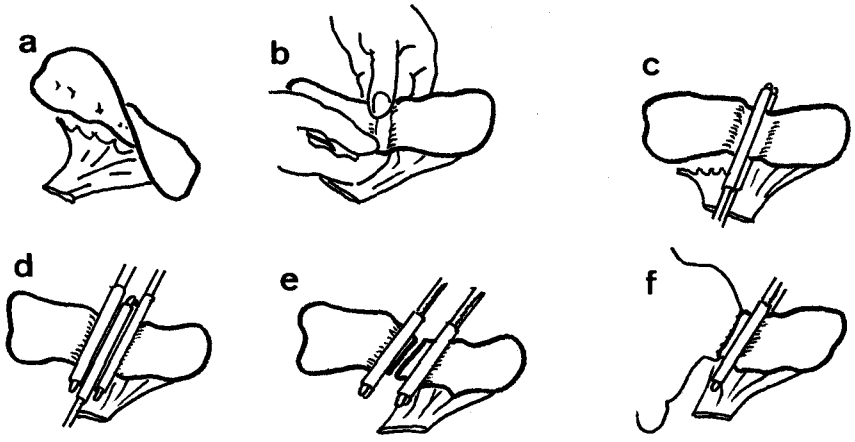

Fig. 7
Partial splenectomy according to De Boer et al. [16]. **a** Arterial ligature. **b** Finger-fracture dissection. **c, d** Placement of three clamps. **e** Sectioning. **f** Oversewing of the remnant. The stages **b** to **f** may also be achieved using an automatic stapler (Nguyen Huu)

Splénectomie partielle selon De Boer et coll. [16]. **a** Ligature artérielle. **b** Digitoclasie. **c, d** Mise de trois clamps de Doyen. **e** Section. **f** Surjet sur la tranche. Les temps de **b** à **f** sont réalisés élégamment en utilisant les agrafeuses automatiques TA (Nguyen Huu)

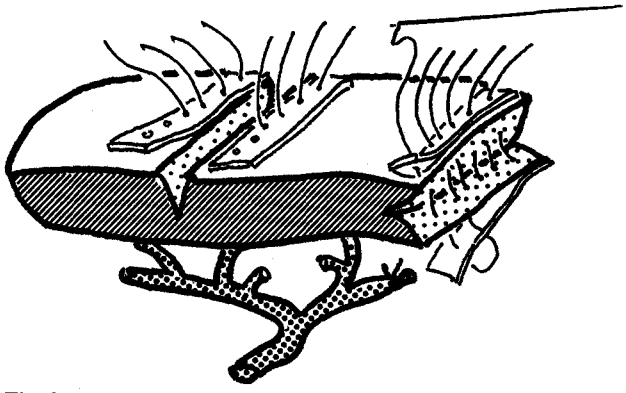

Fig. 8
Splenorraphy and partial splenectomy according to Wolfgang Ruf [60]. Supportive sutures – either straight through or U-shaped – on bolsters strips of perforated silastic

Splénorraphie et splénectomie partielle (d'après Ruf [60]). Sutures appuyées – simples ou en U – sur lanières de silastic perforées

ments may best be distinguished by injecting the segmental artery with methylene blue.

De Boer et al. [16] in 1972 used the fingers to crush the splenic parenchyma before placing three Doyen clamps, removing the intermediate clamp, cutting and then suturing the edges of the capsule with chrome catgut 00 (Fig. 7).

Last year, Dixon et al. [18] described another successful approach combining cutting of the superficial one third of the splenic thickness with a coagulating Yac Laser, and coagulation-aspiration of the pulp followed by ligature or clipping of the vessels in the internal two thirds of the slice.

The splenic parenchyma is reputedly very friable and as far as its suturing is concerned, Wolfgang Ruf et al. [60] suggested either simple straight through sutures or U-shaped sutures supported by two silastic bolsters strips which had been previously perforated (see diagram). No case of immediate or secondary haemorrhage resulted from their experience with nine baboons and one dog (Fig. 8).

Automatic Stapling of the Cut Surface with a TA (Thoraco-Abdominal) Instrument (Figs. 9 and 10)

The principle of conservative surgery to the spleen is once again gaining favour and we thought it might be interesting to review our experiments between 1954–55 vis-a-vis modern technical progress. We have made wide use of automatic stapling machines in pulmonary surgery and we felt that such an instrument might be of benefit in controlled partial splenectomy particulary where the spleen is relatively flat as in the child. For those spleens whose thickness is greater than 2.5 cm, the new generation of automatic stapler, the divergence of the jaws of which is much greater, might prove useful (TA Premium TM).

We therefore operated on 12 dogs between 12.7.78 and 6.24.80. All were adult dogs, with a

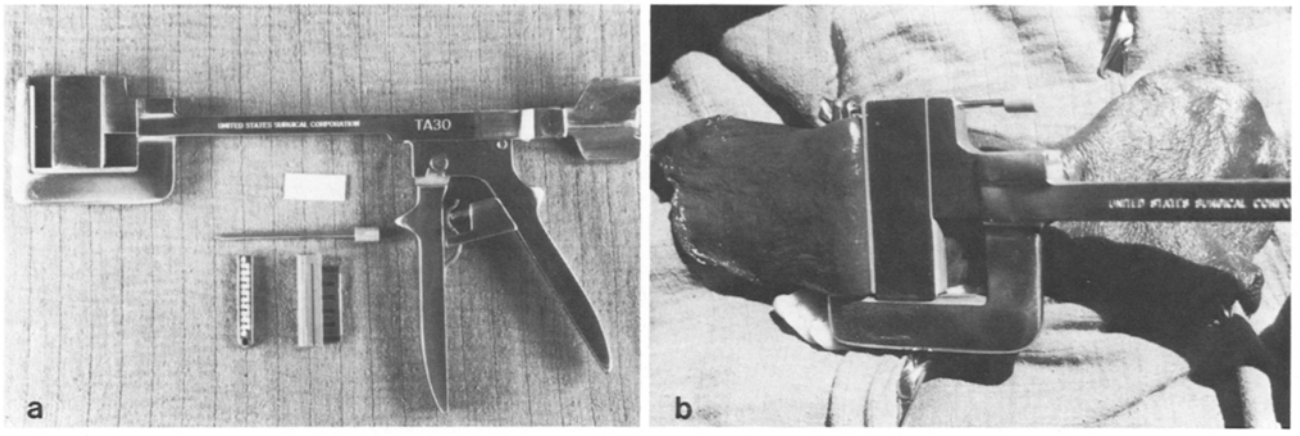

Fig. 9
Controlled partial splenectomy using the thoraco-abdominal automatic stapler (dog). **a** The automatic stapler TA (Thoraco-Abdominal Instrument) and its cartridge of staples ready for use. **b** Application of the automatic stapling machine to the line of the ischemic demarcation (brought about by interruption to the blood supply of the segments to be removed)

Splénectomie partielle réglée au TA (chien). **a** L'agrafeuse automatique TA (Thoraco-Abdominal Instrument) et son chargeur d'agrafes, prêt à l'emploi. **b** Application du TA à la frontière de la zone d'ischémie provoquée (par interruption de l'apport artériel aux segments à enlever)

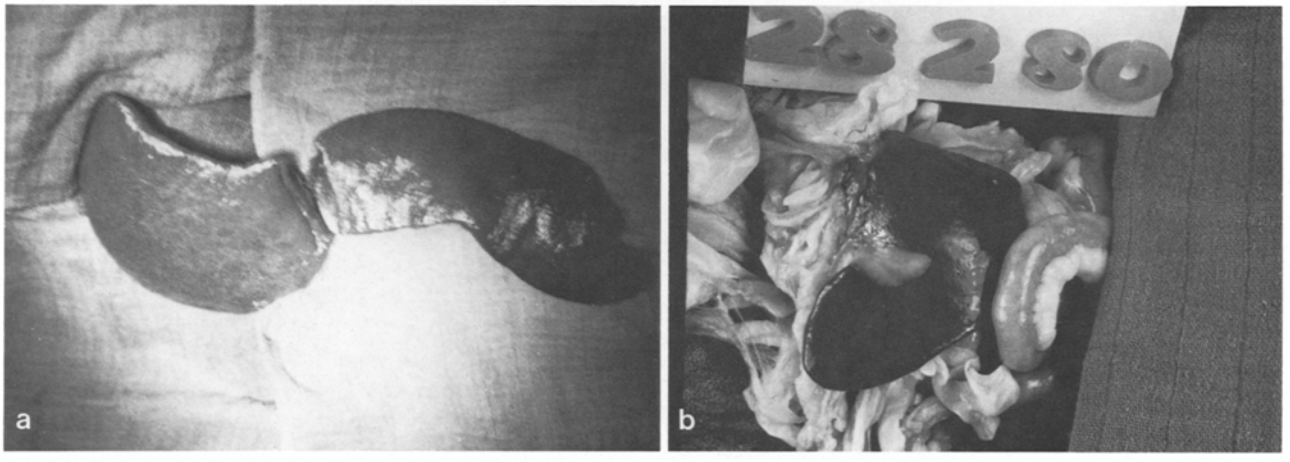

Fig. 10
Controlled partial splenectomy using the automatic stapler (dog). **a** Hemitransection of the spleen along a "bloodless" intersegmental plane, using the GIA stapler (gastrointestinal anastomosis stapler). **b** Result after 1 month and 17 days of a polar ventro-caudal splenectomy: the peritonal cavity is clean; only the greater omentum is found adherent to the cut edge of the spleen

Splénectomie partielle réglée aux agrafeuses automatiques (chien). **a** Hemisection de la rate le long d'un plan exsangue intersegmentaire, utilisant le GIA. **b** Résultat à 1 mois et 17 jours d'une splénectomie polaire ventro-caudale: cavité péritonéale propre, sans adhérences; adhérence du grand épiploon à la tranche de section

weight varying between 15 and 30 kg. They were anaesthetised with Nesdonal and intubated.

By using a midline laparotomy astride the umbilicus, we had no difficulty in exteriorising the spleen which in this animal is long, flat and mobile. It was particularly easy to expose the centro-caudal pole (extremitas ventralis), to the retro-hilar region of which is attached a long, avascular, Y shaped peritoneal fold. After cutting away this fold we located towards the middle of the hilum (hilus lienis), on the lienorenal ligament, the two bifurcating branches of the splenic artery which were very long and passed towards the two poles of the organ accompanied by a large dark vein and a pearl-white nervous plexus.

These two branches gave off numerous penetrating arteries to the spleen (lien), and some rather more scattered branches to the stomach (gaster) and greater omentum (omentum majus) (Fig. 6a).

According to the type of surgery undertaken

(hemisplenectomy, polar splenectomy, segmental mesosplenectomy), we ligated and then cut first of all the gastro-epiploic arteries which might provide an eventual means for the blood to return, then either the terminal bifurcating branch itself, or a certain number of penetrating segmental arteries.

This acute interruption to the blood supply produces, between 1 and 15 min later, marked parenchymal ischaemia. This induced ischaemia may be accelerated either by the injection of adrenalin, or by previous excitation of the periarterial splenic nerves.

The ischaemic zone clearly distinguishes itself from the rest of the organ by its violet, even blackish colour. This colour change became evident either in the form of rectangular bands (mesospleen), or by triangular areas (pole).

When the "bloodless intersegmental line" is well outlined, we tie the satellite vein and then apply the stapler just within its border, in the ischaemic zone. It is then only necessary to run a scalpel along the instrument's jaws to remove the segments to be excised. By this means it is possible to undertake partial resection of the spleen involving two thirds, half, a quarter or one or either poles. The cut edge is straight, clean and in general absolutely bloodless. We have not had to undertake any further haemostasis, either by ligature or by coagulation: One stapler application achieves many steps of other techniques: compression of the splenic parenchyma, and ligature of the scattered vessels packed within the connective network of the spleen (trabeculae lienis).

Care must however be taken in the choice of staple size. In the dog, where the spleen is flat and mobile and thus very compliant, we use either the TA_{30} for its left end, or the TA_{55} for the mesosplenic region and ventro-caudal pole, the staples being the 3.5 or 4.8 according to the thickness of the parenchyma.

The spleen is subsequently replaced within the peritoneal cavity (cavum peritonei) without further manoevres such as incorporation over the cut surface of omentum, muscle or organ. The abdominal wall is closed in two planes using non resorbable synthetic silk.

The dogs recover quickly after operations. We have only had one death. The dogs are sacrificed at intervals from two weeks to nine months (36 weeks) after operation. In all of them the peritoneal cavity was clean without effusion, without adhesions of the organs or intestinal loops, witness to the absence of significant bleeding after closure of the laparatomy. Only the greater omentum (omentum majus) has been found adherent to the cut edge of the spleen (Fig. 10b).

The quality of the scar has been excellent: no evidence of necrosis, splitting, or subcapsular haematoma.

Clinical Step

While the anatomical and experimental steps were achieved at the beginning of the 1950's, clinical application was only realised some ten years later.

Bourgeon who attempted the "first reductive partial splenectomies" in man in 1960, wrote in 1966: "most organs... with a terminal blood supply can be subjected to conservative surgery. The spleen, however, seems to have been made an exception... it seems hazardous or even heretical to raise the question once again in so far as total splenectomy is so ingrained in the minds of surgeons..." [5].

Although we had opened up the way to the vascular segmentation of the spleen both in the anatomical and experimental grounds, the fear of appearing "backward" in our approach sapped our enthusiasm. We did indeed check on the possibility of these segmental resections in some of our patients between 1955–56, but we finished by removing the spleen before closing the abdomen.

We had to wait for the "courage" of Bourgeon who performed since 1960 the first controlled partial splenectomies in man, based on these anatomical and experimental principles [5]. In the Presse Médicale of February 1966, he reported five reductive partial splenectomies followed by thoracic transposition (4 inferior polar, 1 bipolar).

The Brazilian school of Minas Gerais at Belo Horizonte with Campos Christo and coworkers have done much to divulge these anatomical and experimental concepts on which they based their first controlled partial splenectomies in man.

In effect, in two successive articles published in French in the Presse Médicale in 1960 [8] and in English in the Brazilian publication *O Hospital* of 1962 [9], Campos Christo reported respectively on 3 and then on 8 partial resections of the spleen: polar amputation (4 cases), hemisplenectomy (3 cases), mesosplenic resection, followed by suture of the two remaining poles (1 case) (Fig. 11).

Morgenstein from Los Angeles (UCLA) was the first in the United States to undertake partial splenectomy for myelofibrosis in 1966. Much in favour of conservative treatment of the spleen, he recently published (1979) with Shapiro [38], a detailed study of the technique used for 6 controlled partial resections among 42 spleens treated by con-

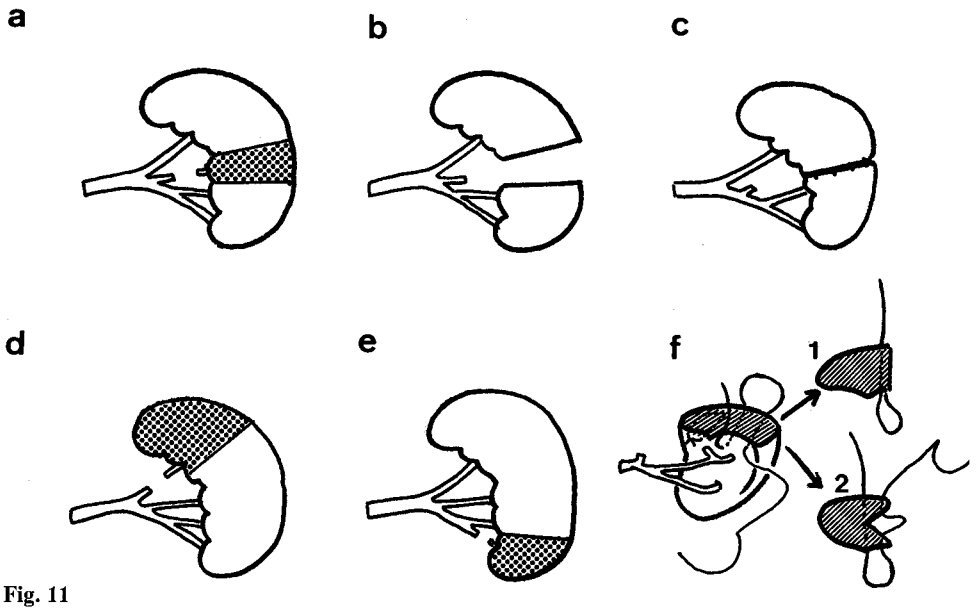

Fig. 11
Controlled partial splenectomy in man (Campos Christo [8]). **a, b, c** Removal of the middle of the spleen. **d, e** Polar splenectomy. **f** Suture of the edge of the section. *1, 2* Cuneiform cut edge [5, 36]

Splénectomie partielle réglée chez l'homme (Campos Christo [8]). **a, b, c** Splénectomie moyenne. **d, e** Splénectomie polaire. **f** Suture de la tranche de section. *1, 2* Tranche cunéiforme [5, 36]

servative surgery (of which 37 were sutured for iatrogenic lesions).

Burrington from Chicago in 1977 [7] undertook two excisions of the upper pole followed by suture of the cut edge by U-shaped stitches using chrome catgut (2 out of 8 treated conservatively).

Mishalany et al. in 1978 [35b] have cited, as an example of conservative surgery, excision of a contused zone of a ruptured spleen split into two fragments followed by simple suture of the two cut edges using Dexon 00.

Strauch [57] in April 1979, described two of his own cases, and collected from the literature 227 cases of partial splenectomy and/or splenorraphy following trauma to the spleen (103 cases described by the Russian Shushpanov).

Dixon et al. [18] from Salt Lake City evaluated in April, 1980, 200 cases which had undergone "partial splenectomy, either subtotal or segmental" which had been successfully published in the literature.

In the light of our brief experience [42] and of the data from the literature, we will try to summarise the different steps involved in a controlled partial splenectomy.

Surgical Approach

The approach should allow broad access to the splenic pedicle and easy mobilisation of the spleen itself.

In children a median laparotomy extending a little way beyond the umbilicus is usually sufficient.

In the adult Morgenstein [36] recommends a combined median/sub-costal laparatomy, or a broad xipho-pubic laparotomy, while Campos Christo [9] prefers either a thoraco-phreno laparotomy passing through the 9th intercostal space, or a laparotomy using Kehr's incision. Bourgeon [5], who undertakes bipolar "reducing spelectomies" with a view to spleno-pneumopexy, uses to thoraco-phreno laparotomy passing through the 9th rib.

Mobilisation and Exposure of the Spleen

Mobilisation of the spleen – necessary for complete examination of damage to the organ and for bringing it out into the operating field – should be carried out carefully, and very gently:

Section, under direct vision, of the ligamentous attachments to the organ (particulary the inferior pole) arising from the greater omentum (omentum majus), the left colonic flexure (flexura coli sinistra), and the diaphragmatic peritoneum: this prevents capsular avulsion when traction is applied to the spleen.

Incision of the posterior peritoneum at the base of the lienorenal ligament (lig. phrenicolienale) and progressive mobilisation with the finger of the tail of the pancreas (cauda pancreatis) in order to bring

it out along with the spleen (lien) towards the midline and through the abdominal incision (surgeon standing to the right of the patient).

Approach to the Splenic Pedicle

Access to the splenic vessels (vasa lienales) is achieved by partially cutting the gastro-splenic ligament, thereby opening the omental bursa [42].

The splenic artery (a. lienalis), whose final prepancreatic segment is easy to locate, may be dissected out and moored by a silicone tape with a view to eventual provisional haemostasis during parenchymal steps. Traction on this tape enables its two or three dividing branches (lobar arteries) as well as their penetrating (segmental) arteries to be located.

Dissection and ligature of the vessels are easily achieved when the pedicle is long and Y shaped, the splenic artery dividing far for from the hilum, more difficult when the pedicle is short and T shaped the shortness of the penetrating arteries leaving little room to move.

Locating the Avascular Intersegmental Planes

All authors have followed our technique when locating the avascular intersegmental planes, by simply rendering the area ischaemic.

Simple interruption of the penetrating artery – by ligature-section or by clamping it – is rapidly followed by clear change in colour of the ischaemic zone which becomes deep violet distinguishing it from the reddish-brown colour of the normal organ. Campos Christo [8] who experimented with injection of methylene blue in the distal segment of the artery in the same way as Simionescu et al. [53], never required this technique in man. During total splenectomy, he did, however, remark that whenever serious haemorrhage occurred, the line of demarcation was late to appear or even absent.

Section of the Parenchyma and Control of Bleeding

After tying off the satellite veins, the capsule should be incised with a scalpel.

Treatment of the underlying parenchyma varies according to the authors: either break the tissue up with a blunt instrument such as curved sissors, the handle of a scalpel or the tip of an suction cannula [36], or crushing the tissue between the fingers [16].

As the dissection progress, each large vessel which bleeds should be located and haemostasis assured by ligature or haemoclip: suction and provisional haemostasis upstream from the lesion[2], facilitates location of the damage.

Campos Christo [9] cuts the parenchyma perpendicularly to the principal axis of the spleen, about 5 mm from the "bloodless plane", within the ischaemic area, such as we showed in our own experiments.

Bourgeon [5] and Morgenstein [36] carry out a cuneiform incision at a deep angle in the splenic remnant in order to bring the edges closer together. These latter in effect suture the cut edge using mattress stitches which approximate the two edges. Oozing from the low pressure sinusoids is controlled by local haemostatics such as Surgicel, Gelfoam or better Avitene [38].

Morgenstein does not agree with electrocoagulation as a means of haemostasis to the parenchyma, believing that thermocoagulation runs a risk of necrosis and secondary haemorrhage.

In conclusion, it may be said that a division by crushing the parenchyma along the bloodless intersegmental plane is not followed by major hemorrhage, supplementory hemostasis being necessary only for a few vessels and sinusoids.

For this reason we believe that the Laser proposed by Dixon et al. [18] could prove interesting, and that the mechanical stapler, as we have shown in our recent experiments, could prove suitable for spleens whose thickness does not exceed 2.5 cm, such as those in children.

Drainage

Once the spleen has been put back, it is wise to place a drain in the left sub-phrenic space, for a period of 24 to 36 h, either a Penrose drain, or a flexible silicone Jackson Pratt drain.

Indications

Ever since the first partial splenectomies, Campos Christo [8, 9] and Bourgeon and Mouiel [5] have foreseen the possible indications of this conservative surgery. The indications have widened considerably in recent years with a better understanding of the fundamental role of the spleen in the immunological defence mechanisms of the organism (Fig. 12):

– thoracic transposition for treatment of portal

2 Tape around the artery [38]; finger compression by an assistant [5]

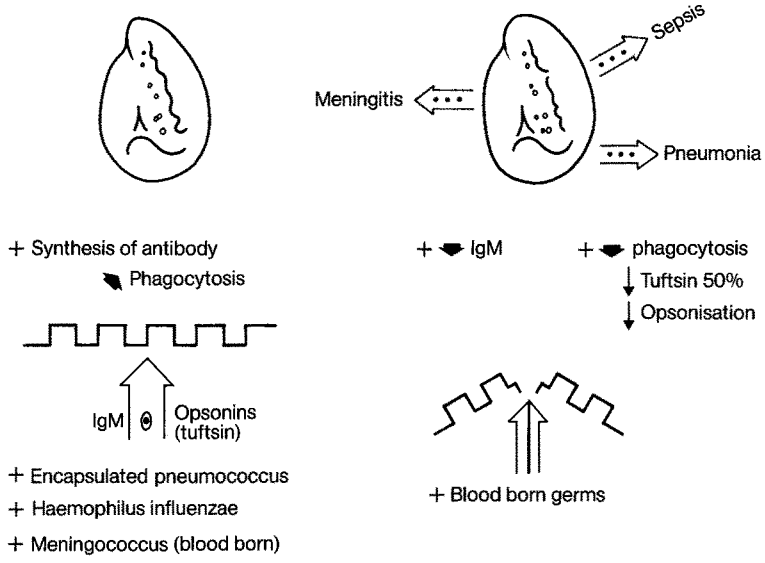

Fig. 12
Diagram to explain immunocompetence according to La Mura et al. [30]. Asplenic or splenectomized children are particularly at risk from the three infections mentioned here. In these children, the infection is usually fulminant, being frequently fatal between the 10th and 18th hour [31]. The spleen on its own represents 25% of the total lymphoid mass of the body [31b] and has three principal functions: 1) removal of particulate antigenes from the circulating blood stream, 2) elaboration of specific immunological responses, 3) production of opsonins

Schéma de l'immunocompétence selon La Mura et coll. [30]. Les enfants aspléniques ou splénectomisés sont particulièrement exposés aux trois germes ci-dessus mentionnés: l'infection prend, chez eux, une allure fulminante avec, souvent, issue fatale entre la 10e et la 18e heure [31]. Trois fonctions principales sont reconnues à la rate qui représente, à elle seule, 25% de toute la masse lymphoïde du corps [31b]: 1) élimination des antigènes particulaires du sang circulant, 2) élaboration des résponses immunologiques spécifiques, 3) production des opsonines

hypertension, and for accidental haemorrhage during splenoportography [5],
- certain spleenic injuries,
- iatrogenic localised laceration, and capsular avulsion during supra-mesocolic surgery,
- benign tumours,
- staging in Hodgkin's disease [56, 57].

Conclusion

Representing as it does some 25% of the lymphoid mass of the body, the spleen plays a fundamental role in the immunological defence against infection (Fig. 12). The indications for "total splenectomy for haemostasis" should therefore be reconsidered.

Being blessed with a terminal type of blood supply, this "blood sponge", is paradoxically divisible into autonomous vascular segments, superposed one upon the other like a pile of plates, and separated one from the other by virtually bloodless intersegmental planes which may be simply demonstrated by inducing ischaemia of the area through interruption of the appropriate penetrating artery approached at the level of the hilum.

This anatomical concept of vascular segmentation, which has been confirmed by animal experiment explains certain "dry ruptures" of the spleen and the shape of certain splenic infarcts. And above all it supports the conservative surgical treatment of the organ, a notion increasingly accepted over the past decade: controlled partial splenectomy, various splenorraphies under cover or otherwise of the segmental artery control.

In more than 300 cases collected from the literature, Morgenstein [38] has not come across a single major haemorrhage necessitating subsequent removal of the entire organ.

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