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RUPTURE OF THE NORMAL SPLEEN

EDWIN W. SHEARBURN

SENIOR THESIS

UNIVERSITY OF NEBRASKA

COLLEGE OF MEDICINE

1936
RUPTURE OF THE NORMAL SPLEEN

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INTRODUCTION

Rupture of the spleen is by no means a new subject. In fact, it has been recognized since before the time of Christ. Yet it is a condition which offers certain difficulties in diagnosis and treatment. At the best, it is a grave condition in which the unfortunate patient is placed, and requires prompt and exacting treatment in order to offer any hope of recovery to the patient. The mortality has been decreased during the last 75 years from 80 percent (82) to approximately 30 percent (15) and perhaps, with the increasing incidence of this problem, due to the increase in automobile accidents, the profession will become more conscious of its possibility of occurrence and more acute diagnoses will be made so that prompt treatment will be afforded. Only in prompt surgical treatment, lies the hope of decreasing the mortality of this condition. It has been estimated that rupture of the normal spleen occurs in about 20-23 percent (77) of the accidents to the abdominal viscera, yet the more frequent occurrences, such as rupture of the stomach or intestine are usually first suspected.

In writing this paper, I have chosen to
deal only with the ruptures of the normal spleen, including traumatic and spontaneous ruptures of that organ. Undoubtedly most physicians are somewhat familiar with the traumatic ruptures of the normal organ, but I suspect that spontaneous rupture if there be such a clinical entity, may seem somewhat paradoxical.

In searching through the literature, I have collected 410 cases of rupture of the normal spleen; 318 of these were traumatic subcutaneous ruptures, 46 were traumatic subcutaneous ruptures with delayed hemorrhage, 26 were open wounds and 20 were spontaneous ruptures, which is, I believe, the longest list of such conditions compiled up to the present time. Black (12) collected 11 and added 1 of his own, making 12, which he presented in 1933.

From this list of cases, I have compiled my own statistics which I have used from time to time in this paper.

Authors, whose collections of 10 or more cases that I have included are:

<table>
<thead>
<tr>
<th>Author</th>
<th>Number of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dretzka (34)</td>
<td>27</td>
</tr>
<tr>
<td>Connors (27)</td>
<td>32</td>
</tr>
<tr>
<td>Bailey (6)</td>
<td>32</td>
</tr>
<tr>
<td>McCracken (60)</td>
<td>20</td>
</tr>
<tr>
<td>Robitshek (83)</td>
<td>128</td>
</tr>
<tr>
<td>Barnes (9)</td>
<td>30</td>
</tr>
</tbody>
</table>

I have endeavored to prepare a paper which is quite complete in the consideration of all approaches to this subject.
ANATOMY

(A) EMBRYOLOGY

The anlage of the spleen appears about the fifth week, (Gray) (40) in embryos of 9mm.,(Arey) (3) as a localized thickening in the dorsal mesentery of the stomach, near the dorsal pancreas,(Arey) (3). The thickening is due to a proliferation of the surface peritoneal cells and their invasion into the underlying mesenchyme which, meanwhile, has also undergone local enlargement and vascularization. Such cells from the peritoneal epithelium give rise to part, at least, of the future spleen. (Arey) (3).

The capsule, trabeculae and pulp cords differentiate directly from the cells of the common mesenchymal mass. The sinuses originate as separate cavities in the mesenchyme, which at first have no connection with the blood vessels. For a time circulation is within a closed system of vessels; the peculiar open-walled sinuses are acquired by the middle of fetal life. Lymphoid tissue appears early but it is not until seven months that the typical splenic corpuscles form ovoid nodules about arteries. During the middle third of fetal
life the formation of white blood cells is supplemented by red corpuscles which develop actively within the splenic mass. (Arey) (3).

The union of the spleen with the omentum is ultimately reduced to a narrow band, the gastro-splenic ligament. (Arey) (3). With the change in position of the stomach the spleen is carried to the left, and comes to lie behind the stomach and in contact with the left kidney. (Gray) (40).

(B) GROSS ANATOMY

The spleen is an oblong and flattened organ, soft and of very friable consistence, highly vascular, and of a dark pulplish color. (Gray) (40). The spleen, if normal, is entirely protected by the ribs. In its position in the left hypochondrium it is in close relationship with several important structures. (51)

The diaphragmatic surface is convex, smooth, and is directed upward, backward, and to the left, except at its upper end, where it is directed slightly medialward. It is in relation with the under surface of the diaphragm, which
separates it from the ninth, tenth, and eleventh ribs of the left side, and the intervening lower border of the left lung and pleura.

The visceral surface is divided by a ridge into an anterior or gastric and a posterior or renal portion.

The gastric surface which is directed forward, upward, and medialward, broad and concave, and is in contact with the posterior wall of the stomach; and below this with the tail of the pancreas. It presents near its medial border a long fissure, or more frequently a series of depressions termed the hilum. This is pierced by several irregular openings for the entrance and exit of vessels and nerves.

The renal surface is directed medialward and downward. It is somewhat flattened, is considerably narrower than the gastric surface, and is in relation with the upper part of the anterior surface of the left kidney and occasionally with the left suprarenal gland.

The superior extremity is directed toward the vertebral column, where it lies on a level with the eleventh thoracic vertebra. The
lower extremity or colic surface is flat, triangular in shape, and rests upon the left flexure of the colon and the phrenicocolic ligament, and is generally in contact with the tail of the pancreas. The anterior border is free, sharp, and thin, and is often notched, especially below; it separates the diaphragmatic from the gastric surface. The posterior border is more rounded and blunter than the anterior, separates the renal from the diaphragmatic surface; it corresponds to the lower border of the eleventh rib and lies between the diaphragm and left kidney. The intermediate margin is the ridge which separates the renal and gastric surfaces. The inferior border separates the diaphragmatic from the colic surface. (Gray)(40).

Except at its hilum the spleen is completely covered by the peritoneum. The phrenico-splenic omentum or lienorenal ligament connects the spleen with the left kidney and the diaphragm. The splenic artery, a branch, of the celiac axis, is located between the layers of this ligament. The gastro-splenic omentum connects the hilum of the spleen with the cardiac end of the stomach. On its way to the diaphragm, the
phrenic-colic ligament, which suspends the colon at the splenic flexure, runs under and supports the spleen. The splenic vein unites with the superior mesenteric to form the portal vein. (51).

The size and weight of the spleen are liable to very extreme variation at different periods of life, in different individuals, and in the same individual under different conditions. In the adult it is usually about 12 cm. in length 7 cm. in breadth, and 3-4 cm. in thickness, and weighs about 200 grams. At birth its weight, in proportion to the entire body is almost equal to what is observed in the adult, being 1:350; while in the adult it varies from 1:320 to 1:400. In old age the organ not only diminishes in weight, but decreases considerably in proportion to the entire body, being 1:700.

Frequently in the neighborhood of the spleen, and especially in the gastrolienal ligament and greater omentum, small nodules of splenic tissue may be found, either isolated or connected to the spleen by thin bands of splenic tissue. They are known as accessory spleens.
They vary in size from that of a pea to that of a plum. (Gray) (40).

The spleen may be marked out on the surface by two horizontal lines from the spinous process of the ninth dorsal and the first lumbar vertebrae. These joined by a vertical line one and one half inches to the left of the midline of the body and another corresponding to the left mid-axillary line forms a space in which the spleen lies obliquely. (68).

(C) MICROSCOPIC ANATOMY

One early observer (91) said that the spleen is practically a complicated lymphatic gland, placed in the circulatory system instead of the lymphatic channel. The splenic tissue is more or less typical lymphatic tissue which fills the spaces between the trabeculae and consists of the red pulp and the white pulp. (58).

The capsule and trabeculae of the spleen consist of dense connective tissue and a few smooth muscle cells. Elastic fibers form a network
between the collagenous bundles. In man, the network of the thickest elastic fibers is located in the deep layers of the capsule. The external surface of the capsule is covered by a layer of flattened mesothelium which is part of the peritoneum.

In the **trabeculae** the elastic fibers are more numerous than in the capsule and sometimes replace most of the collagenous fibers. Muscle fibers are present in small groups in man.

The **white pulp** or lymphatic tissue forms a sheath about the arteries. The stroma is a network of reticular fibers closely joined to the reticular cells. The collagenous fibers of the trabeculae are continuous with the reticular fibers. As in all lymphatic tissue the meshes of the framework are filled with free lymphocytes of various sizes. In the center of the splenic nodules or Malpighian bodies, as in nodules of lymph nodes, the framework consists of very thin, scattered threads, while at the periphery it is coarser and much denser, forming a covering for the corpuscle. In the center of the Malpighian bodies there are often secondary nodules, which appear and disappear in connection
with the general condition of the organism. A few elastic fibers are interspersed among the reticular fibers of the white pulp close to the artery and its capillaries.

The amount of white pulp varies from time to time. The volume and number of the Malpighian corpuscles decrease progressively with age.

The red pulp fills the spaces between the terminal venous blood vessels, the so-called "venous sinuses", and appears in histologic sections as cords, the "splenic" or "Billroth cords" of tissue, running in all directions and forming a spongy framework. The red pulp is a modification of the lymphatic tissue of the white pulp. The red pulp gradually merges into the white at the periphery of the Malpighian bodies; outside of the latter, there is a band of tissue looser than the white pulp and containing some erythrocytes but devoid of venous sinuses. It constitutes the so-called "marginal zone" of the Malpighian body. Some authors include the venous sinuses in the red pulp.
A framework of reticular fibers forms the foundation of the red pulp. At the boundary between the white and red pulp, it is evident that the fibers of the former continue into those of the latter. The collagenous fibers of the trabeculae continue directly into the reticular fibers of the red pulp. The fibrous stroma of the latter is accompanied by fixed macrophages and primitive reticular cells.

In the meshes of this framework are many lymphocytes, free macrophages and all the elements of the circulating blood. The non-granular leukocytes are the most numerous of these free cells. Among them small, medium-sized and large lymphocytes and monocytes are present in great numbers, intermingled without order.

The branches of the splenic artery enter the hilum and pass along the trabeculae, with which they branch repeatedly, becoming progressively smaller in caliber. They are muscular arteries of medium caliber and have a loose tunica adventitia surrounded by the dense connective tissue of the trabeculae. (58).

When the arterial branches have reached a diameter of approximately 0.2 mm. they leave the
trabeculae. At this place the tunica adventitia is replaced by a cylindrical sheath of lymphatic tissue which accompanies the arteries almost to the point where they break up into capillaries. As the white pulp is the transformed tunica adventitia of the arteries, it is clear why its stroma also contains some elastic fibers.

In many places along the course of branching arteries, the lymphatic sheaths are thickened into the globular Malpighian bodies. Sometimes several corpuscles are located in a row along the same artery.

Throughout its course within the white pulp, the artery gives off numerous capillaries which supply the lymphatic tissue of the sheath and of the Malpighian corpuscles. These arterial capillaries pass into the red pulp to unite with venous vessels.

The small arteries in the white pulp continue to branch and become thinner; on reaching a caliber of 40-50 they leave the lymphatic tissue and enter the red pulp. Here they branch into small, straight vessels called penicilli which show three successive parts. The first portion is the longest and is called the artery of the pulp,
which rapidly becomes narrow and divides. Each branch is provided with a characteristic spindle-shaped thickening of its wall, the Schweigger-Seidel sheath, but has a very narrow lumen—the so-called sheathed artery; this portion may ramify into two or three branches. These form the third portion and are the shortest and represent simple arterial capillaries which either do not divide or split into only two branches.

The veins of the spleen begin as networks of venous sinuses which penetrate all of the red pulp and are especially numerous about the Malpighian bodies. The sinuses, even when moderately expanded, occupy more space than the splenic cords between them.

The venous sinuses empty into the veins of the pulp whose wall consists of endothelium supported exteriorly by a condensed stroma of the red pulp and a few elastic fibers. These pulp veins coalesce to form the veins of the trabeculae.

The manner in which the blood reaches the venous system from the arterial system in the spleen is not definitely known.
True lymphatic vessels are found only in the capsule of the spleen and in the thickest trabeculae.

Nervous networks, which originate from the celiac plexus and which consist almost entirely of nonmedullated fibers, accompany the splenic artery and penetrate into the hilus of the spleen. (58).
Removal of the spleen, if records are to be trusted, was practiced, at least in a few instances, before the birth of Christ. It was known to the ancients, and their knowledge has been confirmed in all later times, that the spleen is not essential to life. (Quoted by Moynihan, 68).

Aristotle wrote, "The spleen is not invariably present; and in those animals that have it, it is only present of necessity in the same sense as the excretions of the belly and of the bladder are necessary, that is, of being an inevitable concomitant". He also wrote, "It is the position of the liver on the right side of the body that is the main cause for the formation of the spleen; the existence of which thus becomes to a certain extent a matter of necessity in all animals, though not of very stringent necessity." (Quoted by Moynihan, 68).

About the physiology and the pathology of the spleen, the ancients, Hippocrates, and Galen knew little or nothing, though it is interesting
to recall that the former wrote of bleeding of the nose and from the gums in this connection. Galen enshrouded the whole subject in rather unintelligible mystery. He definitely disagreed with those who stated that the spleen was made for no purpose and suggested that "the residual matters from the liver" are in part attracted to this organ and that "the blood is purified both by the spleen and the bladder, besides the liver. Also that the humours which are decidedly thick and earthly in nature and have escaped alteration in the liver, are drawn by the spleen into itself, thus preventing harm to the organism as a whole." (Quoted by Beer, 11).

Eristratus took the view that the spleen was wholly devoid of use. (Quoted by Moynihan, 68)

The Talmud states that in ancient times runners often had their spleen removed so as to enable them to attain greater speed. (Quoted by Carstens, 23)

Paulus also states that in his time the abdominal wall over the region of the spleen was cauterized with a red hot iron that made a number of eschars, sometimes at least six. (Quoted by Carstens, 23).
Pliny, who lived from 23-79 A.D. wrote, "This member hath a propriety by itself sometimes, to hinder a man's running; whereupon professed runners in the race that be troubled with the spleen have a devise to burn and waste it with a hot yron. And no marveile! for why? They say that the spleen may be taken out of the body by way of incision, and yet the creature live nevertheless; but if it be man or woman that is thus cut for the spleene, he or she looseth their laughter by the means. For sure it is that intemperate laughers have always great splenes." (Quoted by Moynihan, 68).

Caelius Aurelianus, who lived in the fifth century, stated that in ancient times, they cauterized the region of the spleen and put a red hot iron deep into the tissue so as to destroy the spleen. (Quoted by Carstens, 23).

Shakespeare speaks of both of these functions of the spleen:

"Such fantastic tricks
As make the angels weep; who, with our spleen,
Would all themselves laugh mortal."
Measure for Measure II,ii,121.

And of its effect upon the pace of a runner,
the Bastard speaks in "King John":

"I am scalded with my violent motion
And spleen of speed to see your Majesty."
King John, V, vii, 49.

(The above quoted by Moynihan, 68).

1549. The first recorded splenectomy was performed by Adriano Zaccarello. (Quoted by Agnew, 1).

1581. Rousset described the successful removal by Viard of spleens which protruded through wounds in the left side. (Quoted by Moynihan, 68).

1600. Ballonius, stated that a barber removed a portion of the spleen protruding through a wound and the man recovered. (Quoted by Carstens, 23).

1678. Nicolaus Matthia, extirpated a prolapsed spleen. (Quoted by Carstens, 23).

1680. Morgagni describes a successful case of splenectomy in a dog by Zambeccari in Florence. (Quoted by Moynihan, 68).

1696. M. Vauselow gave a history of a case of rupture of the spleen. (Quoted by Ricketts, 82).

1698. Hannaeus removed the spleen protruding through a knife wound. (Quoted by Carstens, 23).

1700. Fantoni reported the removal of a spleen from a little girl, where the spleen was torn out. (Quoted by Carstens, 23).

1711. M. B. Valentinus described a rupture of the spleen in a homicide. (Quoted by Ricketts, 82).
1725. J.G. Scheid exhibited a specimen of a ruptured spleen with the report of the case. (Quoted by Ricketts, 82).

1737. Ferguson reported partial removal of a spleen that was ruptured. (Quoted by Carstens, 23).

1743. Wilson reported a case of splenectomy for prolapse from injury. (Quoted by Carstens, 23).

1776. Clark removed a portion of the spleen from a wound. (Quoted by Moynihan, 68).

1787. Dorsch recorded the removal of a portion of a spleen protruding from a wound. (Quoted by Carstens, 23).

1810. Krauss ligated a protruding spleen and allowed it to slough off. (Quoted by Carstens, 23).

1827. Audauard considered sanguineous congestion and intermittent fevers as a cause of rupture of the spleen. (Quoted by Ricketts, 82).

1828. Schultz recorded that he removed spleens from 24 animals and 23 survived. (Quoted by Moynihan, 68).

1829. Thompson ascribed rupture of the spleen to excessive use of alcohol. (Quoted by Ricketts, 82).

1836. A. Campbell recorded rupture of the spleen and kidney in the same patient. (Quoted by Ricketts, 82).

1841. A. Bardeleben published results of his experiments which were directed towards discovery of the functions
of the spleen. (Quoted by Moynihan, 69).

1844.
Hamilton recorded a rupture of the spleen due to violence. (Quoted by Ricketts, 82).

1857.
Gustav Simon expressed opinion that removal of the spleen was an unwarranted operation. (Quoted by Moynihan, 68).

1869.
Whitney mentioned a laceration of the spleen in pregnancy. (Quoted by Ricketts, 82).

1896.
Lamarkia performed the first splenorrhaphy. (Quoted by Heineck, 46).

1897.
Stengel (91) said, "The spleen is practically a complicated lymphatic gland, placed in the circulatory system instead of the lymphatic channel. Unquestionably this organ bears an important relation to the manufacture of red cells."
ETIOLOGY

(A) SPONTANEOUS RUPTURE

The etiology of spontaneous rupture of the normal, if there be such a clinical entity, is perhaps, the most baffling question relative to this topic.

Byford, (21) advances one theory for rupture of the normal spleen without apparent cause. His opinion is that (1) the spleen is not normal in its entirety and the rupture occurs at a localized diseased area, and this area is destroyed by hemorrhage resulting from rupture. (2) The spleen which ruptures normally is probably due to a slight trauma and is a case of delayed hemorrhage.

Pratt, (79) makes two suggestions, two of which are along the same thought as the above. They are; that a spontaneous rupture of the normal spleen is due to one or more of the following: 1. Subcapsular hemorrhage from a delayed hemorrhage from a not too recent trauma; 2. A lesion of the nature of thrombosis at the surface which would be likely to cause a breach in the capsule, the beginning of a gross hemorrhage. Two such cases have been reported to be due to a
venous thrombosis. Gray (41) reported a case of spontaneous rupture due to a venous thrombosis of both the portal and splenic veins which caused the spleen to be congested and more prone to rupture. Rhame (81) reported another similar case. However, he was not certain that the venous thrombosis had antedated the hemorrhage. For Pratt's third theory as to rupture, he resorts to the physiology of the spleen and points out that the spleen is a muscular organ which contracts rhythmically at the rate of once a minute and more violently and rapidly during any effort. He suggests that the normal spleen, in an effort to meet the demands of the body might contract so violently as to cause an endothelial tear and that this small tear would become progressively larger with each successive contraction.

Two cases of apparently spontaneous ruptures of apparently normal spleens have been reported in which infarcts were thought to be an etiologic factor. Diehl (31) reported a spontaneous rupture following a carbuncle. At autopsy the spleen, or rather the remaining part, was found to be normal both macroscopically and microscopically, but Diehl felt that there had probably been an infarct in the lower pole of the spleen which had been washed free with the
hemorrhage. Miller (66) reported a spontaneous rupture in a patient, who at the time of rupture, had a septic infection of the hand and had had syphilis when examined 20 years previous. Unfortunately, the spleen, in this instance was not subjected to a microscopical study.

Black (12) suggested that age was a pertinent factor in spontaneous ruptures since the spleen, as a rule ages early. He states that at the age of 36, 50 percent show thickening and hyaline changes in the Malpighian bodies and capsule. These degenerative changes tend to rupture. Congestion of the portal vein and its radicles will force blood between the spleen and its investing capsule of peritoneum, giving a subcapsular hematoma. A slight degree of torsion of the splenic pedicle, which in a multiparous subject, would be prone to twist, thereby causing the hematoma to burst. McMenemey and Burnett (64) reported a case of a spontaneous rupture of a normal spleen in a woman in her sixteenth pregnancy which followed a slight strain. The spleen was found to be congested but otherwise normal.

The author has collected twenty cases, from the literature, of spontaneous ruptures of
spleens which were found to be microscopically normal. This list is longer than any one found in the literature and probably represents most of those cases reported up to the present time. (None of the above cases were included in this list).

The sex incidence was preponderantly male, being in a ratio of 3:1. The greatest age incidence was found to be in the third decade of life, six being between the ages of 20 and 30. Four were found in each of the fifth and sixth decades, while the second and fourth decades each showed two.

Two of the cases reported (Connors, 27) Young, 106 were tubercular, and another (Harvey, 45) had had a cough for some years. Connors' case was also an alcoholic as was the case reported by Dardinski (30). Another case (Metcalf and Fletcher) had had pneumonia. Four cases were reported, (Metcalf and Fletcher, 65), (Rhame, 81), (Halliwell, 43), Nixon, 70 in which the patient had drunk or eaten just previous to the rupture. Four cases were engaged in mild muscular activity at the time of rupture, (Susman, 95),
Four cases were either standing, sitting or lying in bed at the time of rupture. The cases of Remynse and Capecci (collected by Bailey) were doubtful cases and little is known about their patients. Skerritt's case is also a doubtful case since death ensued abruptly. The case reported by Bailey did not state any predisposing factors such as mentioned above.

It is evident from the above reports that the term "spontaneous rupture of the normal spleen" may be a misnomer and that careful postmortem examination and complete histories may obliterate this confusing group of rupture spleens.

(B) TRAUMATIC RUPTURE

(1) Subcutaneous
   (a) Immediate

Sub-cutaneous rupture of a normal spleen is much less likely than when the spleen is enlarged due to disease. In the normal spleen, rupture is more likely when the organ is congested, the spleen...
is more friable. (93). The spleen is less subject to traumatic injury than the other parenchymatous organs of the abdomen, largely due to the protection afforded by the overlying thoracic wall. (100). Yet, the spleen is perhaps the most friable of all the abdominal viscera and what, with its tendency physiologically to engorgement, its fragile texture and thin capsule, it is quite prone to rupture when traumatized. In the majority of cases, it is the rapidity and velocity of the trauma rather than the size and shape of the agent causing the injury, that is of etiological importance. The more rapid the blow, the less time the abdominal muscles have to place themselves on guard in order to protect adequately the underlying organs. While a slight trauma may, and has produced these injuries, trauma of the normal spleen is usually due to severe inflections of a degree sufficient to produce other accompanying injuries.

Chavannaz and Guyot estimate that the subcutaneous injuries represent 70-85 percent of the traumatic lesions of the spleen. (Quoted by Vincent and Hanrahan, 100).

Contusions and ruptures of the spleen are
observed in both sexes but occur most frequently in active males between the ages of 20 and 40 years. However, cases have been reported in old people and newborn infants. (100). Of the 318 cases of this type of injury collected by the author, 235 cases were reported as to sex and it was found that 83.9 percent were male and 16.9 percent female, a ratio of approximately 5:1. In the same series of cases, 260 were reported as to age and the following statistics recorded:

<table>
<thead>
<tr>
<th>Age Group</th>
<th>Cases</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td>62</td>
<td>23.8</td>
</tr>
<tr>
<td>10-20</td>
<td>92</td>
<td>35.4</td>
</tr>
<tr>
<td>20-30</td>
<td>47</td>
<td>18.1</td>
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<tr>
<td>30-40</td>
<td>33</td>
<td>12.7</td>
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<td>40-50</td>
<td>15</td>
<td>5.8</td>
</tr>
<tr>
<td>50-60</td>
<td>9</td>
<td>3.4</td>
</tr>
<tr>
<td>60-70</td>
<td>2</td>
<td>0.8</td>
</tr>
</tbody>
</table>

The injury may be occasioned by any form of violence such as blows, kicks, falls, and automobile accidents where a heavy, blunt force is applied to the splenic region and transmitted directly to the spleen through the abdominal or thoracic wall. A few instances of ruptures in indirect violence have been reported, the blow being received on a part of the body some distance from the spleen as
in a fall on the left hip or the right side of the abdomen. One author reported a case of a woman, five months pregnant, whose spleen had been ruptured by a violent act of coitus. (94).

In 311 of the cases collected by the author, the type of injury was reported and the following statistics were attained:

<table>
<thead>
<tr>
<th>Type of Injury</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run over</td>
<td>86--27.7%</td>
</tr>
<tr>
<td>Fell</td>
<td>82--26.4%</td>
</tr>
<tr>
<td>Hit</td>
<td>52--16.7%</td>
</tr>
<tr>
<td>Struck an object</td>
<td>31--9.9%</td>
</tr>
<tr>
<td>Kicked</td>
<td>27--8.7%</td>
</tr>
<tr>
<td>General trauma</td>
<td>21--6.8%</td>
</tr>
<tr>
<td>Auto accident</td>
<td>12--3.8%</td>
</tr>
</tbody>
</table>

(b) Delayed Hemorrhage

Delayed hemorrhage from a traumatic rupture of the normal spleen is usually due to trauma of a milder degree than that producing immediate hemorrhage. It is more often a contusion rather than a true rupture. The same type of injury may be the cause as those which cause a more sudden and profuse...
hemorrhage.

McIndoe (61) collected 45 cases and added one of his own making a list of 46 cases of delayed hemorrhage from traumatic subcutaneous rupture of the normal spleen. Of the 46, only 4 were female. The ages included the years between 8 and 63 with the preponderance of cases between 15 and 50.

(2) Open or Puncture Wounds

In civil life, gunshot wounds of the spleen and stab wounds, are made, in large part, by revolver bullets and knives under conditions of violence, suicide or accident. According to statistics by Schaefer, Berger and Michelsson, (Quoted by Vincent and Hanrahan,100) they occur in a ratio of almost two gunshot wounds to one stab wound. In the World War practically all wounds of the spleen were made by projectiles such as shell fragments, and the bullets of rifles and machine guns. Stab wounds of any kind by bayonets or knives were very rare. Wallace (102) reported two cases of ruptured spleen produced by shell fragments which did not themselves touch the organ. During the Great World War, the same author found the spleen to be wounded 54 times.
in the course of 965 abdominal operations. In only 32 instances was it the only organ involved.

In the series of 27 cases reported by Dretzka (34) he found injury due to gunshot wound in 14 instances and stab wounds in only 4 cases.
PATHOLOGY

(A) SPONTANEOUS RUPTURE

The pathology involved in a spontaneous rupture of a normal spleen is identical with that found in a traumatic subcutaneous rupture of a normal spleen.

(B) TRAUMATIC RUPTURE

It is generally stated that the spleen is involved in about 20-23 percent of all traumatic lesions of the parenchymatous abdominal viscera, but it is probably injured much more frequently than the published observations indicate, since a considerable proportion of the cases do not come under clinical observation. This is especially true in severe injuries, for many of these patients succumb a short time after the injury as a result of the profuse haemorrhage which is the inevitable result of grave traumatism to this organ. (76).

Traumatic lesions of the spleen are divided into (1) subcutaneous and (2) open wounds, according
to the mechanism of the trauma and the absence or presence of a penetrating wound of the body wall. (100).

(1) Straus and Harrison (93) quote classification given by Henschen which classifies subcutaneous ruptures due to the type of rupture found. It includes

(a) Central Contusion Rupture. These may result in traumatic splenomegaly, the formation of an encapsulated hematoma, secondary rupture of an encapsulated hematoma into the peritoneal cavity with serious late intra-peritoneal hemorrhage.

(b) Peripheral Sub-capsular Tangential Contusions Due to Scrapping. These result in the formation of sub-capsular hematomas and blood cysts, which later may suppurate. The hematoma forms beneath the resistant capsule, which may be loosened in one or more places. When the hematoma increases in extent, enlarges, and exerts more pressure on the capsule, the capsule is likely to rupture and be further stripped off.

(c) Isolated Tears of the Capsule.

(d) Tears Involving the Capsule and the Parenchyma. These may be superficial, incomplete,
or through the entire thickness of the organ.

(e) Isolated Tearing Away of One Pole.

(f) Incomplete or Complete Tearing Away at the Hilus.

(g) Isolated Tearing of the Splenic Vein or Artery or Both Vessels. This pathology may also be associated with parenchymatous injury.

Most authors, however, prefer to classify subcutaneous ruptures according to the time following the initial injury that the symptoms and signs of rupture appear. So, these ruptures are more often classified into (a) immediate rupture and (b) delayed rupture. McIndoe (73) (61) chooses 48 hours as an arbitrary time limit. That is, according to him, all ruptures which occurred within 48 hours following the initial injury were considered as immediate rupture and those which did not show signs of rupture for 48 hours or more were classified as delayed rupture.

(a) Immediate Traumatic Subcutaneous Rupture

The capsular tears of true rupture may be single or multiple and involve any part of the spleen.
Vincnet and Hanrahan (100) quote Michelsson as saying that in 50 percent of all ruptures of the spleen, there is more than one tear in the capsule—a point of first importance in the operative treatment of these tears. The same author also quotes Berger as saying that two-thirds of all the tears are transverse. There is a physical basis for this fact. Johnson (49) makes a pertinent observation in advancing Pascal's Law of Hydrostatics to explain the fact that most of the tears are transverse. The law is, that "any pressure exerted on contained fluid will be transmitted equally in all directions."

Since the capsule has more resistance to longitudinal than to transverse stress, most tears are transverse. Johnson (49) also notes that most of the tears are above the level of the pedicle. Multiple tears tend to be radiating rather than parallel, and practically always are accompanied by lesions of the parenchyma which vary from superficial rents to deep lacerations that divide the spleen into one or more fragments. At time one portion of the organ receives the brunt of the injury, as the lowerpole, and is completely crushed or torn away. The large vessels of the pedicle may be severed with a quickly fatal hemorrhage.
Hemorrhage is a prominent feature of these traumatic lesions. The blood may be free in the peritoneal cavity or localized in the forms of intracapsular or perisplenic hematomata.

Scars and fibrous nodules in the spleen result from ruptures that have healed spontaneously. Cysts and abscesses may develop from unabsorbed hematomata.

(b) Delayed Traumatic Subcutaneous Rupture

Delayed rupture is due to a contusion which includes all grades of injury to the parenchyma, torn or crushed, with the formation of small ecchymoses, or a large intracapsular hematoma, which sometimes practically strips the capsule from the body of the organ. (100).

The primary injury to the spleen in these cases may be classified as follows:

1. Minor superficial capsular rupture or slight splenic contusion producing parenchymal ecchymosis.

2. Intrasplenic hematoma and subcapsular hemorrhage without capsular rupture.

3. Capsular and parenchymal rupture with perisplenic hematoma. (61).
The secondary bleeding may be due not only to subcapsular hematomas, but also to secondary rupture of central hematomas; late rupture of a peri-splenic hematoma, which was primarily walled off by adhesions, and late bleeding from loosening up clots of omental adhesions after these have caused the primary hemorrhage to cease, due to a secondary trauma or subsequent torsion of the spleen. (93).

The latent period or period of "symptomatic silence", the period following the initial injury and hemorrhage until the secondary rupture is due to the absolute cessation of all bleeding from the injured organ and to its efforts at repair. It is terminated by the abrupt renewal of profuse secondary hemorrhage under the stress of a slight rise in blood pressure (61) or a second minor injury or may be due merely to a strain.

(2) Open or Puncture Wounds

These injuries may be classified by the type of instrument producing them as:

(a) Stab Wounds
(b) Gunshot Wounds or Wounds Produced by Projectiles.

However, the pathology is essentially the
same in either case, so the two will be considered together.

Open wounds of the spleen are extremely variable in extent and character. The wound of entrance is usually on the left side of the body, although high-powered bullets may injure the spleen after traversing any part of the chest, upper abdomen or pelvis. Often there is no wound of exit. Stab wounds in the majority of cases penetrate the lower part of the left thorax, the wound of entrance corresponding to the 8th, 9th and 10th intercostal spaces between the axillary line and the vertebral column. (100).

All degrees of injury to the organ may occur: penetrating, gutter, perforating, lacerated wounds, or ruptures with separation of a segment. The friability of the tissue is so marked that extreme destruction and large tears are the rule, yet limited, clean-cut wounds occasionally occur. In the majority of cases of wounds by shell fragments deep, irregular fissures radiate from the orifices of entrance and exit, at times completely separating segments of the organ. Moreover, in most cases, as a result of contusion a large part of the parenchyma is converted into an almost fluid pulp. (Fiolle,
quoted by Pool,127)

The splenic pulp when wounded is prone to give rise to profuse hemorrhage. (76). However, the amount of bleeding depends upon the size of the severed vessel. (100). While bleeding is usually very profuse, it may be surprisingly small from perforating wounds that do not tear the splenic tissues. It can readily be seen that the last instance would be more prevalent among stab wounds rather than in the case of a wound due to a projectile where the splenic tissue would be more likely to be torn. Usually the bleeding from the spleen is intra-abdominal. At times, when the missile or knife crosses the lower part of the chest, the hemorrhage is largely intrathoracic, the blood having flowed into the chest cavity through the wound in the diaphragm. Large open wounds of the pleura give rise to a haemopneumothorax. (100).

Besides being very friable, the splenic pulp is peculiarly prone to infection, consequently the late development of an abscess within the organ or subphrenic abscess is not uncommon. (76).

Wounds of the spleen are complicated in most cases by the presence of an injury to other
structures in the abdomen or chest. Hanrahan (100) cites the fact that Schäfer found but one instance of isolated splenic injury in 71 cases.

In thoracic wounds the pleura and diaphragm are always injured, occasionally the lung and rarely the pericardium. (100). Of complicating wounds of the viscera, Pool (76) quotes Fiolle: "Of complicating injuries of abdominal viscera in war-wounds of the spleen, wounds of the small intestine have most frequently been reported; after which, in order of frequency, lesion of the colon, the left kidney, and the stomach are seen as associated injuries, and the pancreas and the liver being much more rarely wounded." Wallace (102) on the other hand, found the kidney the most frequently involved.

A traumatic hernia of the spleen may result from prolapse of the organ through a wound of the abdomen, or one corresponding to the 9th and 10th intercostal spaces of the thorax. It occurs more frequently in stab wounds, but is comparatively rare in either form of injury. The prolapsed spleen wounded or uninjured, may protrude partially or
completely from the wound of entrance. It is rapidly seen that such accidents do not occur unless the pedicle of the spleen is elongated. According to Moynihan (67), the immediate cause of protrusion is a sudden increase in intra-abdominal muscles at the moment of injury which squeezes the spleen through the wound in the body wall. If the organ is completely herniated, the lips of the wound may so compress the pedicle as to interfere with the blood supply and cause engorgement, intracapsular hemorrhage or gangrene.
SYMPTOMATOLOGY

The symptomatology of rupture of the normal spleen may present a varied and complex picture. There is no definite clinical picture of rupture of the spleen. (90). In general, the symptom complex is that of intra-abdominal trauma and hemorrhage. (100).

At the outset, there is usually marked shock. (93). The period of shock which immediately follows the trauma is of short duration and usually clears up before the onset of the signs of hemorrhage. When the bleeding begins at once and is steadily progressive, the symptoms of shock merge with the symptoms of hemorrhage and the two periods cannot be distinguished. In other cases, after the recovery from shock there is an interval of improvement before the onset of a secondary relapse which has been called, by Baudet, the latent period. (Quoted by Vincnet and Hanrahan, 100). The last condition is found in those cases of delayed hemorrhage. During this latent period the patient usually has some abdominal pain and the abdomen, if examined will present moderate signs suggestive of internal injury. (100). The latent period usually lasts
from a few hours to one or two days and rarely exists for days or weeks and the patient goes about his work in the belief that the primary injury is not of much significance. The latent period in such cases is due to the absolute cessation of all bleeding from the injured organ and to its effect at repair. It is terminated by the abrupt renewal of profuse secondary hemorrhage under the stress of a slight rise in blood-pressure. In McIndoe's (61) series of cases of delayed hemorrhage of over 48 hours, he found that the latent period varied from 2 to more than 30 days. The author found that in 234 cases of traumatic subcutaneous ruptures of the spleen, that 105 or 11.9 percent went into shock.

Abdominal pain is practically always present, is chiefly localized to the left side of the abdomen, is aggravated by all movements, progressively increases in severity and later extends over the entire abdomen. (93). The author found pain to be present in 131 cases of 55.9 percent.

The pain is not infrequently referred by way of the phrenic nerve through the 3rd and 4th cervical roots to the shoulder and left arm. Willis (105)
cited this symptom as being of great diagnostic importance. He said the pain was referred from the diaphragm and was due to the subphrenic irritation from blood clots around the spleen. The author found this symptom (Kehr's sign) to be present in 11.5 percent of the cases.

Occasionally, there may be pain in both shoulder. (1.8 percent).

Vomiting may be present (21.3 percent) or there may be merely nausea. (3.9 percent).

Later the patient may complain of thirst (6.9 percent) and shortly thereafter of air hunger (8.5 percent). (83).

Pallor is usually marked, due to the progressive and gross hemorrhage. (83).

The facial expression is anxious and the patient soon becomes restless. The temperature may at first be subnormal, later rising above normal. Respiration soon become rapid, and are usually shallow and thoracic. The pulse is at this time a very important sign, diagnostically as well as prognostically. Increasing tachycardia goes hand in hand with continuous loss of blood and is a significant sign. (83).

The abdominal manifestations of rupture
are tenderness, (52.9 percent), rigidity, (55.8 percent), distention, (19.6 percent) and the local signs of hemorrhage. Distention is a late rather than an early symptom, and is present only after the abdomen is filled with blood. Rigidity and tenderness may be general, but like the abdominal pain are most marked in the splenic region. An intracapsular hemorrhage (delayed hemorrhage) may be revealed by a tender, gradually increasing splenic tumor. (100).

When the blood is free, in the abdominal cavity, there may be shifting dulness in both blanks (42.3 percent). More often the blood is confined to the left side of the abdomen by the formation of blood clots, and gives an area of dulness, that does not shift when the patient is turned upon the right side. (15.8 percent). (100). This fixed dulness in the left loin and the splenic region is called Ballance's sign (120) and was thought by Ballance (8) to be pathognomonic of splenic injury. However, it is conceivable that the same sign might be present if other structures in the left abdomen, as the liver or mesentery of the bowel were source of the bleeding.
Kraft (55) reports a rather infrequent symptom, that of pain shifting to the lower right quadrant, due to a paralytic ileus, producing an obstruction of the bowel, but this is a rare symptom.
46.

**DIAGNOSIS**

A definite diagnosis of rupture of the spleen is rarely made preoperatively. As a rule, only a presumptive diagnosis can be made. Especially in the case of spontaneous rupture, is this true. In the case of traumatic rupture, a diagnosis is made based on the history of a blow in the splenic region and left sided abdominal manifestation indicating an internal injury. (100). In the case of a penetrating wound, there are not symptoms that point definitely to a wound of the spleen. In these cases, too, only a presumptive diagnosis can be based on the presence of a left-sided penetrating wound of the thorax or abdomen, the apparent direction of the wound, track and local signs indicating an internal injury. (100).

There is considerable variability in the evolution of the clinical signs, owing to the character of the internal hemorrhage which dominates the symptoms. (61). Bland-Sutton (13) pointed out, that the patient may collapse as dramatically as when an aortic aneurysm has burst. Thus, the accident may be brought into the category of those better known conditions capable of producing sudden death, and should always be borne in mind in the investigation.
of such an occurrence, particularly if the injury is recorded as having been sustained in the region of the spleen. (61).

In making a diagnosis of rupture of the spleen, a careful history is essential. The history should include the time of the accident, the nature of the accident and the type of resistance met whenever possible.

The symptom complex consisting of shock, immediate or past, together with signs of internal hemorrhage, together with a history of left sided trauma, makes one suspect rupture of the spleen.

Mazel (59) felt that the following symptoms and signs were sufficient to make a diagnosis of rupture of the spleen:

1. History of left-sided trauma.
2. Pain in the left chest and shoulder.
3. Signs of internal hemorrhage.
4. Abnormal rigidity.
5. Difficulty in breathing.
6. Increasing dulness in upper left quadrant.
7. Signs of external injury.

In the case of delayed hemorrhage, McIndoe (73) found that patients did not complain during the latent period, yet the physical signs were still
present if carefully looked for – those of slight rigidity, dull pain and slight acceleration of pulse rate. Then with the later sudden onset of signs of severe internal hemorrhage and in conjunction with the appearance of Ballance's sign, elevation of the left diaphragmatic dome, or pain in the left shoulder the diagnosis could be made somewhat accurately. (61).

Ballance (8) felt that the fixed dulness in the left loin and the splenic region was not present in intra-abdominal hemorrhage from other organs and that it was pathognomonic of rupture of the spleen but this has been disputed by other authors. (100).

If liver dulness is present, the omentum or spleen will be involved – that is, a case of hemorrhage without free gas. However, as distention of the intestine occurs early in these cases, the liver dulness, is often absent, and then diagnosis is impossible. (48)

McIndoe (61) states that rigidity in abdominal contusions not limited to the injured point is of paramount diagnostic significance and is a clear indication for immediate laparotomy.

Elliot (quoted by Robitshek, 83) lays stress on the value of costal resistance or the
force encountered in depressing the various segments of the costal arch toward the vertebral column as an important diagnostic sign.

Though the injury has been severe and the patient suffers great pain, his pulse may be slow in rate and of moderate volume. He may show no signs of loss of blood nor at the time of examination has he lost much blood. Two or three day later, when he seems to be convalescing he is attacked with a severe pain in the abdomen, faints and quickly passes into a condition indicating severe internal hemorrhage. (63).

Signs of pneumonia, pleurisy or effusion may be found at the base of the left lung. (32).

The absence of bruises, abrasions, discolorations and ecchymosis should never mislead one, nor should the diagnosis be allowed to be obscured by other frequently accompanying severe injuries. Among such are fractured ribs, fractured bones other than ribs, kidney injuries, liver lacerations, ruptures of the pancreas, injuries to the lungs, intestines and so forth. (83)

Radioscopic examination aids in diagnosis. The shadow of the spleen may be visible on the screen and a shell fragment, or bullet may be localized on
the organ. (76).

Thorotrast has been used in diagnosis of trauma of the liver and spleen when physical signs were obscured by any cause whatever. (18).

In the early stages of rupture, there is often leukocytosis without diminution in the count of red blood cells or the percentage of hemoglobin. As in any rapid and profuse hemorrhage, the red count and hemoglobin percentage do not indicate the amount of the blood volume. (100). Pool (76) emphasizes the significance, in hemorrhage of this early and rapid rise in leukocytes not accompanied by a relative fall in hemoglobin and red cells.

"In a traumatic hemoperitoneum in the male, examine first the spleen". (Bailey) (7).
Differential Diagnosis

It is often possible to make a diagnosis of a ruptured abdominal organ but it usually is difficult to be certain as to which of the abdominal viscera it may be. (86)

The diagnosis for which rupture of the spleen is often mistaken is a perforation of a gastric ulcer. Halliwell (43) and Patey (72) reported such cases. With a perforation of the stomach or intestine, there is air in the abdomen. (86). Bailey (6) considers vomiting a point against the diagnosis of rupture of the spleen, although it does not occur in 21.7 percent (21.3 percent - author's statistics) of the cases of rupture of the spleen. Dretzka (34) cites the fact that vomiting is more often present in stomach or intestinal perforation. Another point is that with perforation of the stomach or intestine, peritonitis usually follows. (86). Also with a perforation of the intestine or stomach, shock is not so profound and there is usually a relatively quick recovery from the shock. With a perforation of either the stomach or the intestine (duodenum) the pain is either to the right or in the epigastric region and only rarely in the left hypochondrium. The rigidity is usually localized in somewhat the same manner. (29).
If the spleen is adherent to either the stomach or intestine, rupture sometimes causes hematemesis or melena which makes differentiation difficult. (86).

In the case of rupture of a hollow viscus, such as the stomach or intestine, the pain is not so severe as that produced by rupture of the spleen, liver or kidney. (34).

Rupture of the liver is another condition which at times is difficult to differentiate from rupture of the spleen. Buxton (20) quotes Finsterer as saying that injury of the liver is followed by bradycardia and injury of the spleen by increased frequency of the pulse. However, neither give definite reasons for such a phenomena. Peritonitis usually follows rupture of the liver. (86).

Injury to the kidney can be practically ruled out by examination of the urine, passed or catheterized. (93). However, 1:8 percent of the author's cases (collected by the author) had hematuria, thereby making the diagnosis more difficult. (48).

Rupture of the bileducts, ureters or bladder is promptly followed by a peritonitis with much less shock at the outset. (86).

Bronaugh (15) brings up the point that whenever Kehr's sign is present, it is important to
rule out coronary occlusion which would be done on history of previous heart disease, age and condition of the peripheral vascular system.

While ruptures of the pancreas rarely occur without concurrent injury of some adjacent organ, they may occur. Da Costa (29) quotes Wohlegemuth and Noguchi as claiming that within a few hours of a pancreatic injury, there is an increase in the diastase in the blood and in the urine. At the same time, there occurs a sharp rise in blood sugar.

Mesenteric thrombosis manifests itself in most cases as a paralytic obstruction arising suddenly in an individual who has cirrhosis of the liver or valvular disease of the heart, who has had ulcerative endocarditis, an injury or an operation. Gangrene and peritonitis follow paralysis of that section of the bowel. (DaCosta) (29).

Dodd (32) points out that in chest injuries, ruptured spleen complicates fracture of lower ribs sufficiently often for the possibility of its occurrence to be always seriously considered and that these patients should be observed in bed for at least two weeks.

The differential diagnosis of rupture
of the spleen and internal hemorrhage from other causes and from beginning peritonitis, and from rupture of the stomach or intestine is difficult and often impossible. The determining finding, pointing to intra-peritoneal hemorrhage, is evidence of the presence of a rapidly increasing amount of fluid. But the value of this symptom is limited, due to the fact that collections of less than a quart are not demonstrable when the patient lies on his back. The demonstration of air free in the peritoneal cavity of course, speaks for rupture of the stomach or intestine. (93).
TREATMENT

Treatment of rupture of the normal spleen, whether it be spontaneous or traumatic, resolves into two processes. These two processes are:

1. Treatment of shock.

The treatment of shock includes the ordinary methods known to every physician. First, the patient is to be kept warm to prevent further shock. Then he should be given some sort of stimulant. DaCosta (29) feels that ephedrine given in doses of 1–2 grains, is the best drug in the group of stimulants. Caffeine is also used. Then the fall in blood-pressure must be counteracted and if the systolic pressure is below 80, this is best done with intravenous infusion of 500–1000 cc. of 0.9 percent salt solution. Occasionally 5–10 percent glucose solution is used in normal salt solution. This relief is prompt but very temporary. Blood transfusion offers more permanent aid but it seldom happens that a donor with matched blood is at hand to call on. If the blood-pressure (systolic) is above 80, then salt solution containing 6 percent gum acacia should be given hypodermoclysis or proctolcysis. Absolute
quiet is essential in the treatment of shock. Stimulative enemata may be used. (DaGosta)(29).

The arrest of hemorrhage is accomplished by means of operation. Some surgeons feel that it is inadvisable to wait until the shock subsides before operation,(93) (11), while others feel "that it is unpardonable to operate on a patient suffering with systemic shock." (34).

There is a wide variation in the choice of anesthesia. Spinal anesthesia has been used successfully (59) as well as ether, gas, local, or local and ethylene. (93)

Operation may be one of three types:
1. Splenorrhaphy
2. Tamponade
3. Splenectomy

Splenorrhaphy or suture of the tear in the capsule is limited to superficial ruptures involving only the upper surface of the spleen.

It is not practical in tears of the lower surface.

In order to completely explore the spleen including the lower surface, it is necessary to divide gastro-splenic and phrenico-splenic ligaments, thereby rendering the spleen mobile, which presents the operator with the danger of later torsion and
and necrosis of the organ.\textsuperscript{(93)}.

**Tamponade** is rarely justified and is resorted to only in case of poor condition of the patient, when it seems imperative to stop operation quickly in order to treat the shock of the patient.\textsuperscript{(93)} One operator (44) reports a case in which a tear in the spleen was packed with paraffined gauze and a part left to act as a drain. He reported successful recovery.

**Splenectomy** is in most instances the operation of choice.\textsuperscript{(93)} It was used in 82.4 percent of the cases collected by the author. Fowler\textsuperscript{(36)} that there have been reported 23 abdominal incisions exclusive of the thoraco-laparotomy and transdiaphragmatic routes.

The mode of performing splenectomy varies with the position of the organs, and this concerns not only the best site for exposing the organ but also the method of securing the pedicle.

When the spleen is of normal size and retains it proper relations with the stomach, the vessels can easily be secured by transfixing the pedicle with a double ligature as in ovariotomy. Occasionally the tail of the pancreas has been included in the ligature but this is of no
consequence, except that additional care must be exercised in tightening the ligatures. As soon as the spleen is detached, the tissues of the pedicle, being elastic, quickly recede from view, and slip away under the left costal arch (13).

In the case of open wounds of the spleen, it is important at the time of operation to remove all foreign material, blood clots, and devitalized tissue to prevent sepsis (100). In the case of high explosive shells, the irregular fragments carry into the tissues bits of clothing laden with organisms and deposit these along the tract, the walls of which are devitalized by the rough fragments. Such devitalized tissue acts as an admirable medium for the growth of pathogenic microorganisms. (76).

Several men have reported practicing autotransfusion at the time of splenectomy as a means of saving life in such an emergency. (103) (55) (80).

This method was originated in 1914 by Thies, a German gynecologist, who used it successfully in three cases of ruptured extra-uterine pregnancy. (Quoted by Watson 103).

This procedure is usually resorted to when there is no suitable donor at hand or the situation is so precarious that delay would be fatal. The escaping
blood found in the peritoneal cavity is collected in sterile vessels, strained through sterile muslin, citrated and returned into the median basilic vein. (80).
PROGNOSIS

Up to the end of the eighteenth century all cases of rupture of the spleen were considered absolutely fatal. (83). Even as late as 1865 until 1875 the mortality was 80 percent, decreasing from 1876 until 1885 to 45 percent and 20.68 percent between 1886 and 1895. Between 1896 and 1903 the mortality is given as 12-15 percent. In 1904, it is recorded as 50 percent. (82).

Harrison and Straus quote Berger as stating that 92.7 percent of all unoperated cases die and that 90 percent of these patients die from hemorrhage. (93).

One author, in 1932, gave the mortality as 30 percent. (59). In the series of cases collected from the early part of the nineteenth century to the present, the mortality was 26 percent.

It is very rare that spontaneous healing of a ruptured spleen occurs. However, cases have been reported in which encapsulated, localized collections of blood, demonstrable by percussion in the region of the spleen, have later become absorbed. Furthermore, several cases have been reported in which individuals who have sustained a severe injury to the
abdomen, and have later died from some other cause, have, at post-mortem, shown healed tears in the spleen. (93). Ballance (8) cited the fact that splenic blood clotted faster than the blood throughout the rest of the body, and this in a way explains why blood clots will form over the tear in a spleen and cause a cessation of the hemorrhage until the blood pressure is restored. Yet, on the other hand, rupture of the spleen must be considered as a condition capable of producing sudden death. The patient may collapse and death follow immediately. (Bland-Sutton 13).

Mazel (59) states that the prognosis varies inversely with the lapse of time between injury and surgical interference.
Perhaps it would be best to state briefly some of the functions of the spleen before we consider those changes produced by removal of the spleen.

The functions of the spleen are not fully understood. However, Moynihan (69) has grouped its activities in relation to four separate systems.

The Haemopoietic System: In embryonic life, red cells and leukocytes are manufactured here—-a return to this function is seen in the leukemias and in infection in adult life. The Malpighian bodies give rise to leukocytes, and the endothelial cells of the splenic pulp may, under certain circumstances, proliferate and be thrown off into the circulation. It has been suggested that the spleen secretes a hormone which acts on the bone marrow; a rapid anemia occurs after splenectomy and it is possible that this is due to the absence of such a hormone. An intraperitoneal injection of splenic extract in such a case has been shown to cause an increase in the red cells and hemoglobin. A substance which restrains the production of white cells has been supposed to be present, and its absence after splenectomy held to be the cause of the
leukocytosis which constantly occurs.

The Reticulo-endothelial System: The spleen is the most important single member of this system. The pulp cells are capable of taking foreign particles circulating in the blood stream, effete red cells, and perhaps also blood platelets and circulating organisms. Broken-down red cells are carried, probably in endothelial cells, to the Kupffer cells of the liver. Organisms such as the malaria parasite and the Spirochaeeta pallida extracted from the blood may be stored in the spleen. The pulp cells have a further function in combating infections by the manufacture of immunizing substances, and it is for this reason that the spleen is constantly enlarged during the course of generalized infections; a lowered resistance to infections is one of the (theoretical) after-results.

The Digestive System: The volume of the spleen varies during the day, an increase occurring during the three or four hours after a meal. It may be that there is some connection between the variations in the size of the spleen and the leukocytosis which occurs during the digestion.

The Sympathetic-endocrine System: The sympathetic nervous connections of the spleen are very
intimate, and it has been shown that the injection of splenic extract causes a contraction in smooth muscle. A connection has been suggested between the spleen, the thyroid and the thymus gland.

Kahn (52) states that the spleen is also a storehouse for iron, especially the iron which is liberated from the decomposition of the blood tissues.

Studies on dogs in which splenectomy has been performed showed that there was 1. an anemia of red cells and hemoglobin, which tends to recover, the hemoglobin being reduced more than the red cells. 2. An increased resistance of the erythrocytes. 3. The lessened tendency to jaundice when hemolytic agents are administered. (Krumbhaar & Musser) (56).

Studies on man following removal of a normal spleen reveal the same effects as those produced in dogs and a few subjective symptoms.

Ballance (8) reported the following symptoms following splenectomy in an adult man:

1. Progressive loss of strength and loss of weight.
2. Extreme anemia; aspect withered and sallow.
3. A daily rise in temperature.
4. Increasing frequency of pulse.
5. Fainting attacks with great pallor of surface.
6. Headache, drowsiness, thirst, voracity.
7. Diminished or increased secretion of urine.
8. Griping pains in abdomen and tenderness along the long bones.
10. Certain typical blood changes.

Hamilton Bailey added:

11. Attacks of palpitation when lying on the left side due to the loss of the support of the diaphragm.
12. Attacks of vomiting due to the loss of the spleen which predisposes to passive congestion of the stomach.

Ballance goes on to explain that the above symptoms become manifest some ten to fourteen days after operation, continue in great severity for a fortnight, and then show a slow but perfect convalescence.

In children who rapidly convalesce without suffering any obvious distress from the loss of the organ, presumably because their red marrow at once assumes
the functions of the lost spleen, hunger is a marked symptom and the urine is at first diminished in quantity. In adults, who become ill during convalescence, great thirst if complained of, and the urine for a time is increased in quantity.

The pain in, and tenderness along, the long bones would appear to be accounted for by the active changes which are proceeding in the marrow. Ballance cites that Riegner had to amputate the leg of his patient, and thus had the opportunity of demonstrating in the marrow of the amputated human tibis the change from yellow to red marrow which was already known to occur in the tibis of old spleenless dogs.

Studies of the blood-platelets following splenectomy for the rupture of a normal spleen showed a post-operative increase beginning on the sixth day and reaching a maximum of 1,640,000 on the twelfth post-operative day. (87).

Another observer states that the Schilling picture shows a moderate shift to the left in the first one or two hours post-operatively, after which it remains stationary or returns to normal. (15).

Relative to the compensatory changes on the part of the body for the loss of the spleen, Faltin and Stubenrauch, (quoted by Connors) (27), found at the
time of second laparotomies, one and six years, respectively, that the peritoneum was covered with numerous nodules, showing microscopically the characteristics of splenic tissue, which certainly had not been present at the first operation. Smyth (90) had similar cases.

On operation for traumatic hernia some years later, Eccles and Freer (35) found and apparently normal spleen at the same site where a spleen had been removed some years previous. It was normal in every respect.

The statistics from a large number of autopsies show accessory spleens to be fairly common. They are usually situated near the spleen and may be connected with the mother-organ by bridges of splenic tissue or only by a portion of the capsule. They are generally wholly isolated, however, and are situated in the gastro-splenic omentum, great omentum or transverse mesocolon. They vary in size from pinpoint to several centimeters in diameter. It is reasonable to assume that the spleen found by Eccles and Freer (35) at a secondary operation was a hypertrophied accessory spleen. (20).

It is apparently clear to a certain extent at least, that after splenectomy, the functions of the
spleen are taken over by remnants of splenic tissues left at operation, accessory spleens and the rest of the reticulo-endothelial system, all of which show hypertrophy. (11).
CONCLUSIONS

1. Rupture of the normal spleen is a condition which may cause sudden death, due to hemorrhage, or in which hemorrhage may be delayed due to the formation of a subcapsular hematoma.

2. The incidence of rupture of the spleen is on the increase, due to the constant increase in the number of automobile accidents, and therefore it should behoove the practitioner to be always conscious of the possibility of this condition being present.

3. Traumatic rupture of the spleen occurs predominantly in males due to the fact that they lead the more active life.

4. The greatest incidence of rupture of the normal spleen is during the active periods of life.

5. Spontaneous rupture of the normal spleen may be a misleading term.

6. There is not definite clinical picture of rupture of the normal spleen.

7. A preoperative diagnosis of rupture of the spleen is rarely made. Usually, laparotomy is warranted due to the signs of internal hemorrhage.

8. Operative procedures offer the only hope for recovery and splenectomy is the operation of choice.
9. Splenectomy is usually followed by a secondary anemia which in time will return to normal.

10. The body compensates for the removal of the spleen by hypertrophy of the lymphatic tissue, formation of spleniculi and hypertrophy of accessory spleens, if there be any present.
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