The Spleen

Anatomy, Physiology and diseases

Ahmed H. Al-Salem

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Ahmed H. Al-Salem
Consultant Pediatric Surgeon and Pediatric Urologist
Al Sadiq Hospital
Saihat, Saudi Arabia

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Preface

The spleen is a fascinating and mysterious organ with multiple functions. Our understanding of the spleen and its functions has improved over the years, and efforts were made to study the structure, functions, and anatomy of the spleen. The spleen is known to have a unique anatomy and physiology, and because of this, the spleen is considered an important organ for the body. The spleen acts as a filter for the blood but also has important immunological functions. Malpighi, the founder of microscopic anatomy, provided a comprehensive account of the histology and physiological functions of the spleen; over the past 50 years, significant advances have been made in our understanding of the spleen, its functions, and splenic surgery. The first splenectomy described in detail was carried out by Adrian Zaccarelli, in 1549. The work of Campos Christo in 1962 about the segmental anatomy of the spleen helped surgeons perform a partial splenectomy, thereby avoiding complications of post splenectomy infection. With the recent advances of minimal invasive surgery, laparoscopic splenectomy and partial splenectomy have been shown to be feasible and safe both in adults and children.

Over more than 20 years of experience in the field of pediatric surgery, I decided to write this book on the spleen. This is different from any of the already written textbooks. It is actually a well-illustrated, easy to read and quick reference book. It is written in a simple, point-by-point manner, making it useful for consultant surgeons, hematologists, pediatricians, fellows, specialists, residents, and nurses. The book covers most important areas of the spleen including its history, physiology, functions, and various diseases that affect the spleen. Splenectomy, partial splenectomy, and post splenectomy overwhelming sepsis are also covered, with emphasis on the most important points relevant to patient management including clinical, operative, radiological, and hand-drawn illustrations.

Saihat, Saudi Arabia — Ahmed H. Al-Salem

Acknowledgments

I would like to express my special thanks of gratitude to my family who supported me all these years as well as all my patients and their families.

Secondly, I would also like to thank all my friends who helped me a lot in finishing this project.

Contents

Introduction and History

1

- The word spleen is derived from the Greek σπλήν (*splḗn*), and it represents the equivalent of the heart in English.
- It is stated in the past if a person is to be good-spleened (εὔσπλαγχνος, *eús-plankhnos*) then he is a good-hearted or compassionate person.
- For many years the spleen is known to be an organ of interest for physicians and they considered the spleen as a fascinating organ that is full of mysterious.
- The spleen is known to have many more functions than any other organ in the human body (Figs. 1.1 and 1.2).
- Many facts and functions of the spleen however remains unknown today and the spleen still remains a fascinating organ as it was in 400 BC, the time of Hippocrates.
- Galen (in the second century) described the spleen as "an organ full of misteries", "mysterii pleni organon" (Fig. 1.3).
- Plato on th other hand stated that the spleen was created in order "to maintain the liver bright and pure" (Fig. 1.4).

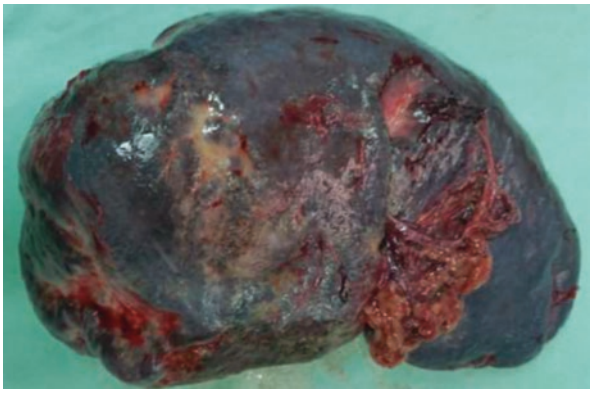

Fig. 1.1 Clinical photographs showing enlarged pathological spleens from a patient with hemoglobinopathy

A. H. Al-Salem, *The Spleen*, https://doi.org/10.1007/978-981-99-6191-7_1

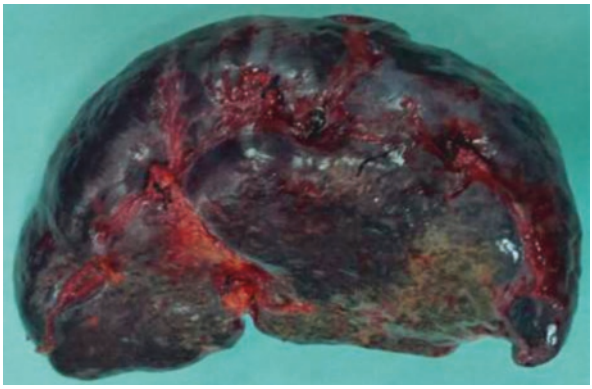

Fig. 1.2 Clinical photographs showing enlarged pathological spleens from a patient with hemoglobinopathy

Fig. 1.3 Aelius Galenus or Claudius Galenus (Greek: Κλαύδιος Γαληνός; September 129—c. AD 216), often Anglicized as Galen (/ˈɡeɪlən/) or Galen of Pergamon. He was a Greek physician, surgeon and philosopher in the Roman Empire. He was also considered to be one of the most accomplished medical researchers of antiquity. Galen influenced the development of various scientific disciplines, including anatomy, physiology, pathology, pharmacology and neurology as well as philosophy and logic (Portrait painting of Galen by Ferdinand Georg Waldmllen)

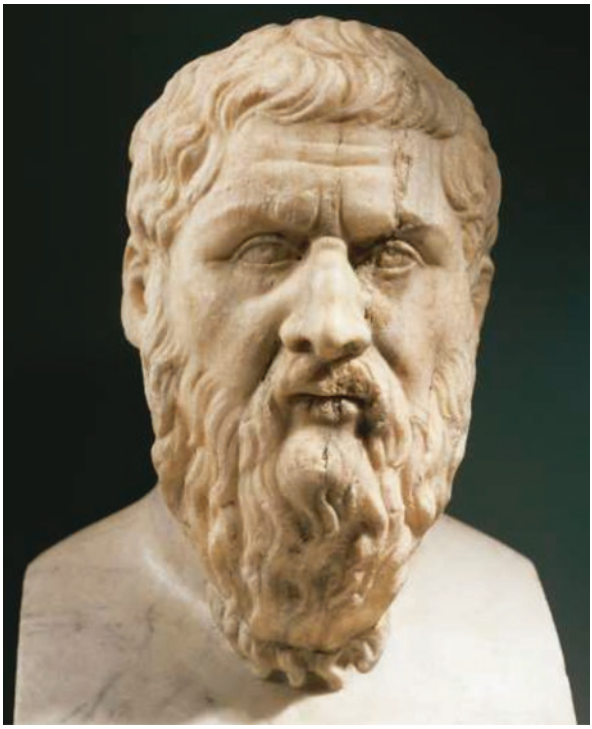

Fig. 1.4 Plato (/ˈpleɪtoʊ/ PLAY-toe; Greek: Πλάτων *Plátōn*; was a Greek philosopher born in Athens. He established the the first institute of higher learning in Europe (Platonist school of thought and the Academy). He was considered a central figure in the history of Ancient Greek philosophy (History and Society by Constance C. Meinwald)

- Hippocrates described the spleen to be soft and fibrous.
- Aristotle (384–322 BC) described the anatomical position of the spleen in the human body (Fig. 1.5).
- Hippocrates stated that the spleen is essential to life and it produces the "black bile", one of four vital humors. He also described with remarkable accuracy the anatomy of the spleen.
- Celsus described the spleen as "a completely unknown organ". He also stated that the main function of the spleen is to secret melancholy humors of the blood through the splenogastric vessels.
- There were others who considered that the spleen function is "to balance the left part of the body with the right one".
- On the other hand, the spleen was also considered by many to bee "a useless Organ and should be removed" (Fig. 1.6).
- One of the main functions of the spleen that was considered is tht the spleen was responsible for producing "black bile". Black bile is one of the four humors of the body that are responsible to make person healthy. Any imbalance f these humors will result in sickness. If a spleen made too much black bile, it would make someone sad or depressed.
- The spleen is also responsible for cleansing the bile and it is thought that this function is responsible for the feeling of happiness and laughter.
- Hippocrates was the first to describe with accuracy the anatomy of the spleen.

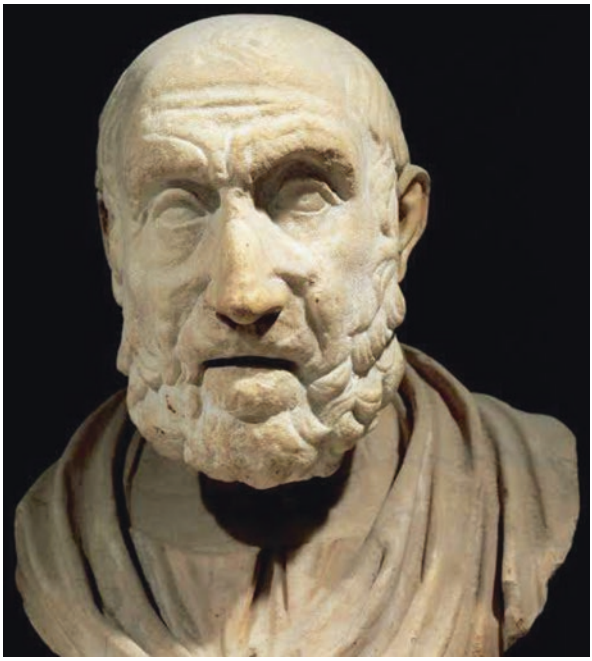

Fig. 1.5 Hippocrates of Kos (/hɪˈpɒkrətiːz/; Greek: Ἱπποκράτης ὁ Κῷος, translit. *Hippokrátēs ho Kôios*; c. 460—c. 370 BC), also known as Hippocrates II, was a Greek physician. He was considered as one of the most outstanding physcians in the history of medicine. He is also known as the "Father of Medicine". He contributed to the growth and development of medicine including the prognosis and clinical observation of diseases, the systematic categorization of diseases, and the humoral theory. He established medicine as a profession and revolutionized it through the Hippocratic School of medicine (Science and Tech byWesley D. Smith)

Fig. 1.6 Aulus Cornelius Celsus (25 BC-50 AD) was a Roman encyclopedist. He claimed and stated that the spleen is an unknown organ and the main function of the spleen is to produce and secrete melancholy humors of the blood. This is secreted through the splenogastric vessels (Science and Tec by Encyclopedia Britanica)

- He was also the first to emphasize the importane of the spleen and stated that the spleen plays a vital role in life. Accordig to Hipporates the spleen produces the *"black bile"*, one of four vital humors of the body.
- The spleen was described as an important site to remove black choler from the body (Gray, 1854; Burton, 1989). Black choler is considered by Hippocrates (c. 460–380 bc;) as one of the four humors of the body. These humors regulate bodily functions.
- Black choler, or also known as black bile, when in acess is responsible to the state of unhappiness and inactivity. Excess of black bile results from failure of the spleen to absorb and remove it from the body.
- This possibly represents the earliest concept of hyposplenism.
  - While blood (hot, sweet and red)
  - Phlegm (cold and moist)
  - These two were considered beneficial humors to the human body.
  - Black choler (cold, dry and thick)
  - Yellow bile (hot, dry and bitter)
  - These were considered non desirable humors to the human body.
- The yellow bile was known to be excreted into the small intestine via the gallbladder.
- The route of excretion of black choler on the other hand was unknown. Black choler function was to belived to create a balance and counteract the effects of the two hot humors. Black choler was also belived to give mourishment to the bones of the body.
- Hippocrates claimed that the spleen function is to absorb the watery elements from the food in the stomach while the gallbladdwe takes the yellow bile from the liver.
- Celsus on the other hand stated that the main function of the spleen is to secret the melancholy humors of the blood and this is done via the splenogastric vessels.
- There were others who considered the spleen a useless organ, and should be removed.
- Paracelsus was one of them and he wrote that the spleen was a superfluous organ that should be removed when it becomes diseased (Fig. 1.7).
- Vesalius was born in Brussels, which was then part of the Habsburg Netherlands.
- Vesalius was another physician who considered the spleen unessential to life. To prove this, he removed the spleens of many animals without adverse effects (Fig. 1.8).
- Vesalius was a professor at the University of Padua (1537–1542) and later became Imperial physician at the court of Emperor Charles. He was also considered as the founder of modern human anatomy.
- Erasistratus (310–250 BC) was a Greek anatomist and physician. He was the first to observe and document that internal organs of the human body appeared to be organized symmetrically to either side of the midline.
- Aristotle and Erasistratus and because of this symmetrical arrangement of the human internal organs thought that the spleen represented a left-sided equivalent of the liver.

Fig. 1.7 Paracelsus (full name Philippus Aureolus Theophrastus Bombastus von Hohenheim), was a Swiss physician and considered the father of toxicology. He described the spleen as a superfluous organ that should be removed when it becomes diseased (History and Science by John G. Hargrave)

Fig. 1.8 Andreas Vesalius (Latinized from Andries van Wezel) (/vɪˈseɪliəs/; 31 December 1514–15 October 1564). He lived in the sixteenth-century and was considered an anatomist and a physician. He also published one of the most influential books on human anatomy, De Humani Corporis Fabrica Libri Septem (*On the fabric of the human body in seven books*) (Science and Tech written by Marcel Florkin)

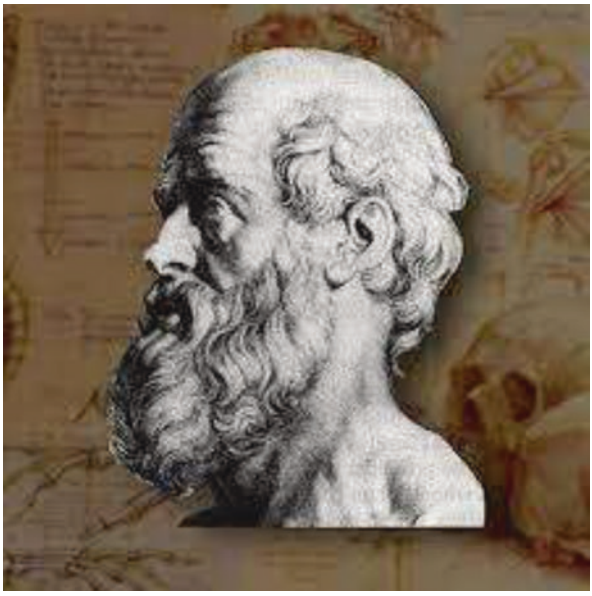

Fig. 1.9 Erasistratus (/ˌɛrəˈsɪstrətəs/; Greek: Ἐρασίστρατος; c. 304—c. 250 BC) was a Greek anatomist and royal physician under Seleucus I Nicator of Syria. Erasistratus and Herophilus were the founder of the school of anatomy in Alexandria. And he also helped establish the methodic school of teachings of medicine in Alexandria. He also together with Herophilus establish neuroscience and studied nerves and their roles in motor control through the brain and skeletal muscles (Science and Tech by Encyclopedia Britanica)

- Erasistratus also stated the spleen is not a useful organ and had no function of its own (Fig. 1.9).
- Galen was the first to identify and describe communicating structures between the spleen and the stomach. These were called Galen's gastro-splenic communications.
  - He also described nourishment for the spleen via thick juices produced by the liver.
  - The remaining of these secretions which can not be handeled by the spleen were delivered to the stomach via the gastro-splenic communications and subsequently excreted.
  - He also described the spleen as "an organ full of misteries", "mysterii pleni organon".
- Vesalius in 1725 challenged Galen's gastro-splenic communications and described the true nature of the vasa brevia of the stomach.
- Vesalius showed that the vascular supply of the liver and the spleen are different and the spleen can not be considered as a supplementary liver.
- Nonetheless Vesalius supported Hippocratic concept with the spleen acting as a filter of black bile from blood (Figs. 1.10, 1.11 and 1.12).
- In the Ancient Babylonian, Egyptian, Greek and Roman times the spleen was considered an organ that weakened men and horse's athletic capacity.
  - One contributing factor for this is the fact that many of these patients had splenomegaly as a result of malaria infection and this will impair their atheletic ability.
  - To improve the running ability of horses and men a variety of techniques were adopted to reduce the size of the spleen.

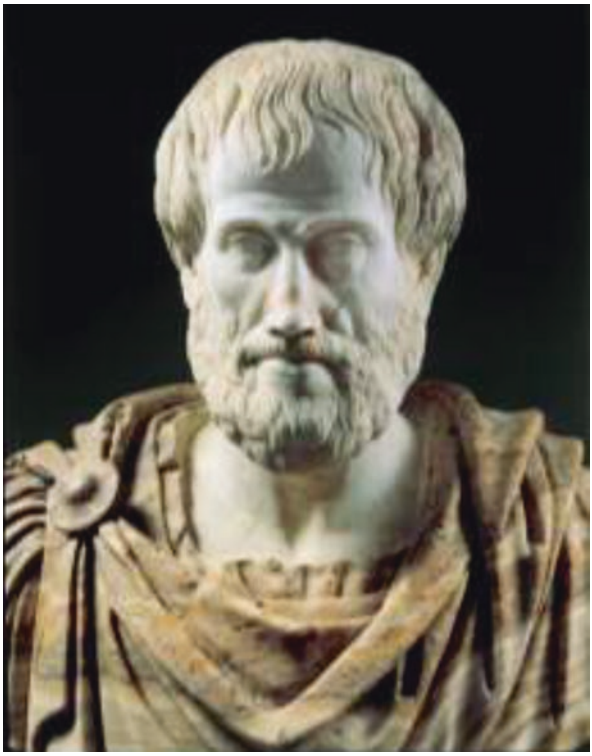

Fig. 1.10 *Aristotle* and Erasistratus thought that the spleen represented a left-sided equivalent of the liver in the human body (History and Society written by Anthony J.P. Kenny Anselm H. Amadio

Fig. 1.11 *Aristotle* and Erasistratus thought that the spleen represented a left-sided equivalent of the liver in the human body (History and Society written by Anthony J.P. Kenny Anselm H. Amadio

Fig. 1.12 Galen (Aelius Galenus or Claudius Galenus) was a Greek physician, surgeon and philosopher in the Roman Empire Science and Tech written by Vivian Nutton)

  - One of them was cauterizing the left flank of the body in an attempt to shrink the size of the spleen.
  - A red-hot iron was used to achieve this procedure.
  - Splenectomy was another adopted procedure and performed to improve the atheletic ability of men and horses and allow them to run faster.
  - Macht and Finesilver in 1922 tested this theory on mice in the laboratory at Johns Hopkins University. They concluded that asplenic mice were able to run faster than mice with an intact spleen.
- The first study on the vascular pedicle of the spleen is attributed to Julius Caesar Arantius, in 1571 (Fig. 1.13).
- One of the important discoveries of Julius Caesar Arantius is the hippocampus.
- Marcelo Malpighi (1628–1694)
  - He studied the morphology of the spleen and described the spleen capsule and its intraparenchymatous insertions and the spleen microanatomy.
  - Malpighi accurately described the splenic capsule and the trabeculae that accompany the distributions of vessels.
  - This was done via injections of china ink into the vessel lumen.
  - He also identified and described the splenic follicles which are named after him (Malpighian corpuscles). These are known as lymphoid follicles of the spleen which form the white pulp of the spleen.
  - He described these follicles as excretory glands filled with liquids and suggested that they their contents were releaed into trabeculae and then into veins to be carried elsewhere in the body by the bloodstream.
  - He described accurately the organization of the arterial and venous system of the spleen.
  - Malpighi also postulated that these follicles played a role with secretion of bile by the liver.

Fig. 1.13 Julius Caesar Aranzi (Giulio Cesare Aranzio, Arantius) (1530—April 7, 1589) was well koown for his contributions to human anatomy. He was a famous anatomist and surgeon of the sixteenth century (The free social encyclopedia)

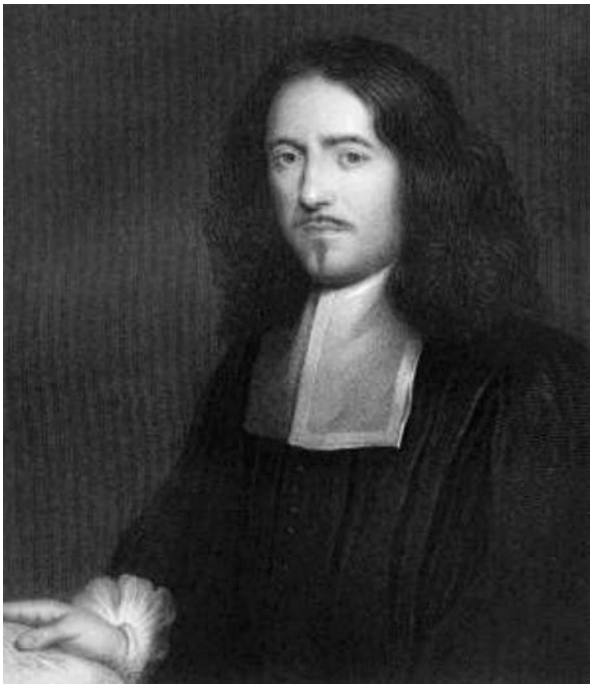

Fig. 1.14 Marcello Malpighi (10 March 1628–30 November 1694) was an Italian biologist and physician. He was known as the "Founder of microscopical anatomy, histology & Father of physiology and embryology". He also identified the splenic follicles which are now called the "Malpighian bodies of the spleen" or Malpighian corpuscles (Science and Tech by Ettore Toffoletto and Alfredo Riva

- Malpighi performed a splenectomy on a dog with no adverse effects apart from increased appetite and weight gain.
- Henry Gray on the other hand considered that the function of Malpighian corpuscles was to regulate and balance the level of albumen in the blood. He also noted that they became atrophied in starved animals. Gray considered that the function of Malpighian corpuscles was to add albumen to the blood (Fig. 1.14, 1.15 and 1.16).

Fig. 1.15 Henry Gray FRS (1827–13 June 1861) was a British anatomist and surgeon. He published the famous anatomy book which is named after him (Gray's Anatomy) (From Wikimedia Commons)

- In 1777, Hewson classified the spleen as part of the lymphatic system of the body.
- Hewson in the 1780s suggested that the spleen played a role in haemopoiesis.
- Hewson considered the spleen to play an important role in the production of red blood cells which were initially colorless and subsequently becomes red in color.
- Some of the patients with splenomegaly were found to increased white cells in their blood suggested that the spleen was also responsible for white blood cell production.
- Julian Evans
  - In 1844, he gave a medical presentation to the Royal Society in London.
  - At the end of his presentation, he made the conclusion that Malpighian corpuscles were lymphatic glands and that the spleen had two sets of functions.
    The first function is that the spleen act as a multiloculated reservoir.
    The second function of the spleen is to separate fluid from blood, a function carried by the Malpighian corpuscles and this then secreted into efferent lymphatics (Fig. 1.17).
- The spleen is considered part of the lymphatic system of the body and resembles a large lymph node.
- The spleen infact is the largest lymphoid tissue of human body and it accounts for 25% of total body lymphocytes.

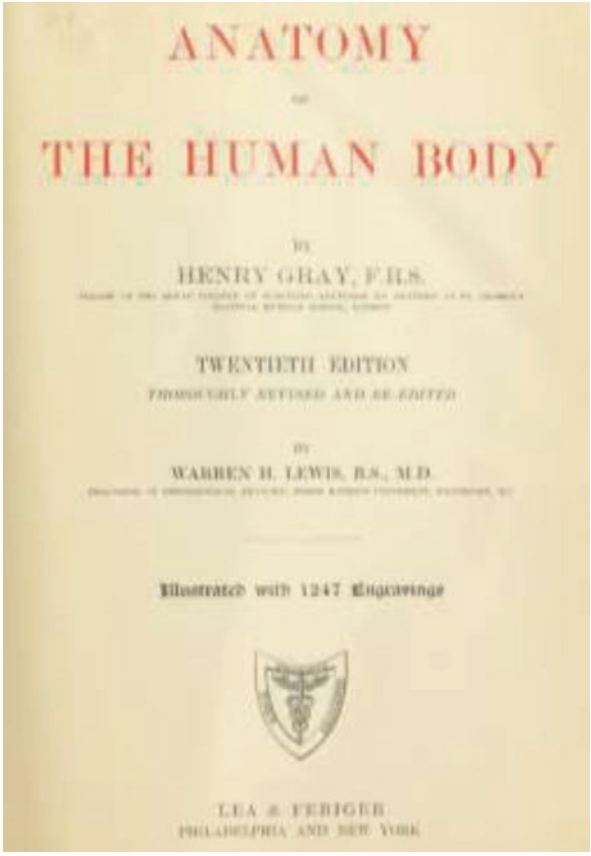

Fig. 1.16 Henry Gray FRS (1827–13 June 1861) was a British anatomist and surgeon. He published the famous anatomy book which is named after him (Gray's Anatomy) (From Wikimedia Commons)

- The spleen is a valuable organ and splenectomy should not be done unless the spleen becomes pathological (Figs. 1.18 and 1.19).
- In 1701, Ruysch studied the microanatomy of the spleen. He injected spleens with wax and concluded that the bulk of the spleen is made up of a vascular network (Fig. 1.20).
- In the 1820s, erythrophagocytosis function of the spleen was described. The spleen was considered an important organ responsible for removal of senescent red cells from the circulation.
- Virchow suggested that cell death was not a normal natural process and was always a sign of disease.
  - Virchow contributed a lot to clinical medicine and was the first to describe and name diseases such as leukemia, chordoma, ochronosis, embolism, and thrombosis.
  - Virchow was the first physician to establish a link between the origin of cancers from otherwise normal cells.
  - He also described Virchow's node which are supraclavicuar lymph nodes.

Fig. 1.17 William Hewson (14 November 1739–1 May 1774) was a British surgeon, anatomist and physiologist. He was known as the "father of haematology"(Science and Tech by Encyclopedia Britanica)

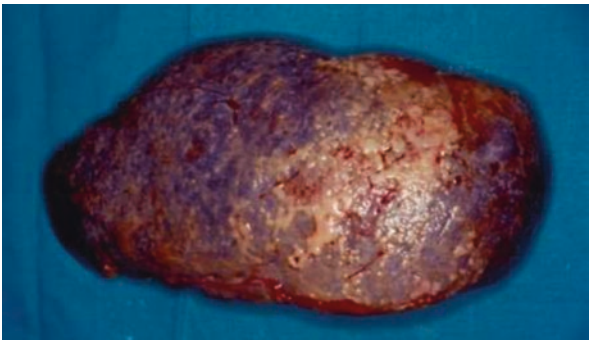

Fig. 1.18 Clinical photographs showing enlarged pathological spleens with multiple small infarcts

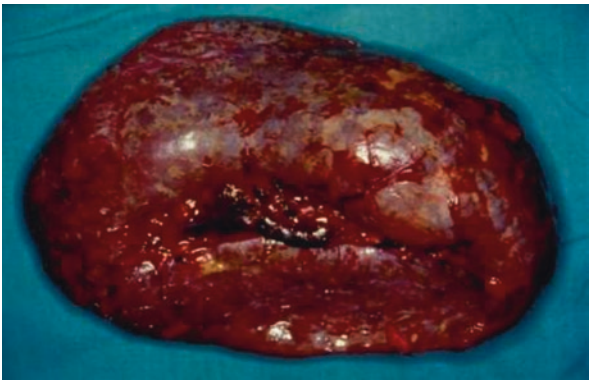

Fig. 1.19 Clinical photographs showing enlarged pathological spleens with multiple small infarcts

Fig. 1.20 Frederik Ruysch (Dutch: March 28, 1638—February 22, 1731) was a Dutch botanist and anatomist. Ruysch, in 1701, injected spleens with wax to study and evaluate their microanatomy (Wikipedia, the free encyclopedia)

  - The supraclavicular lymph nodes when found on the left side are called Virchow's nodes.
  - These are indicative of a mass that can be recognized and when this is the case, clinically tis is called Trosier sign.
- Theodor Billroth, a famous surgeon who developed the technique of gastrectomy. He became famous because of this technique which bear his name today.
  - He described the microanatomical structure of red pulp cords of the spleen and emphasized the idea that a major function of the splenic red pulp is haemopoiesis (Figs. 1.21 and 1.22).
- Ambroise Paré de Laval described the first case of a traumatic hernia of the spleen.
- Otis in 1876 described traumatic hernia of the spleen in more details. He reported 16 cases from the American War of Rebellion.
- Jaboulay in 1893 introduced the term "exosplenopexy". In this technique he extracts the spleen partially into the wound and sture it to the edges of the wound. This way he was iatroenically creating hernia of the spleen in the left upper quadrant of the body. This made a traumatized spleen accessible and easier to control bleeding.
- Subsequently, Pallavecchio used the term "Exosplenolisi". He used to use thermocautery to destroy the herniated part of the spleen rather waiting for spontaneous atrophy of the extruded part of the spleen (Fig. 1.23 and 1.24).
- Splenosis:

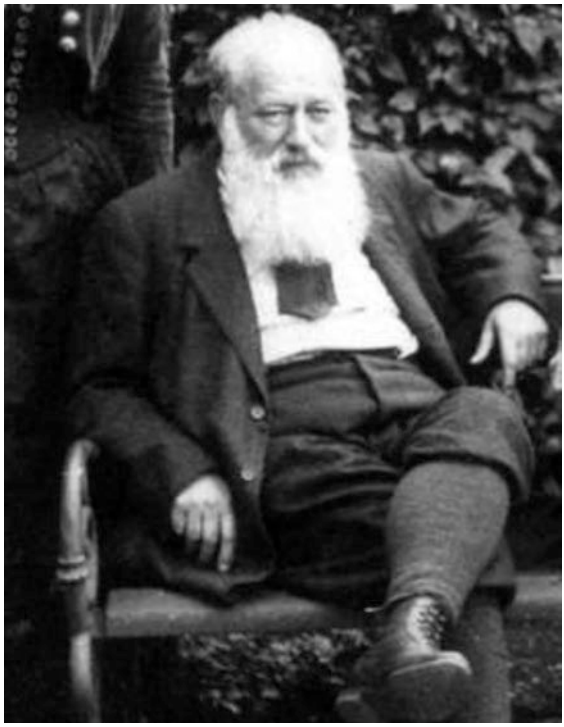

Fig. 1.21 Christian Albert Theodor Billroth (26 April 1829–6 February 1894) was a German and Austrian surgeon and a musician. He is known as the founding father of modern abdominal surgery (Science and Tech by Encyclopedia Britanica)

Fig. 1.22 Rudolf Ludwig Carl Virchow (13 October 1821–5 September 1902) was a German physician. He was also known to be an anthropologist, pathologist, prehistorian, biologist, writer, editor, and politician. He is known as "the father of modern pathology"and as the founder of social medicine. He was also called the "Pope of medicine" (Science and Tech by E. Ashworth Underwood)

Fig. 1.23 Ambroise Paré (c. 1510–20 December 1590) was a French surgeon who served kings Henry II, Francis II, Charles IX and Henry III. His main contribution was in surgical techniques, forensic pathology and battlefield medicine. He also contributed to the treatment of wounds and invented several surgical instruments (Science and Tech by Encyclopedia Britanica)

Fig. 1.24 Mathieu Jaboulay (5 July 1860–4 November 1913) was a French surgeon. His main contribution was in techniques of vascular anastomosis. Jaboulay also was the first to introduce the term proposed "exosplenopexy" (Wikipedia, The free encyclopedia)

- Following splenic trauma and injurey, part of the spleen will scatter throughout the abdominal cavity. Some of these cells and in the presence of adequate blood supply they will grow and form small spleens splenunculi.
- This process is called splenosis.
- Splenosis is not rare and about 1 in 5 people have accessory spleens.
- H. Albrecht (1896), in Germany was the first describe splenic implant in the peritoneum, after a trauma.

THE FIRST DESCRIPTION OF SPLENIC IMPLANT IN THE PERITONIUM AFTER HUMAN TRAUMA WAS REPORTED BY H ALBRECHT (1896) IN GERMANY (SPLENOSIS).

- In 1911, Kocher advocated excision of the spleen following trauma. This is to stop the bleeding. He also stated that no side effects will follow its excision.
- Following this everybody advocated splenectomy for every indication.
- The first documented splenectomy for trauma was performed in 1590.
- Following this many splenectomies were performed following injury to the spleen.
- The first splenectomy in America for trauma was performed in 1816.
- In 1962, Campos Christo established the segmental anatomy of the spleen.
- His work encouraged surgeons to perform partial splenectomy.
- In 1590, Dr. Viard performed the first partial splenectomy. He used a piece of string to stitch a segment of the spleen following a small abdominal wound.
- The first successful partial splenectomy for trauma was reported by Franciscus Rosetti in 1590 (Fig. 1.25).

- **THE FIRST DOCUMENTED SPLENECTOMY FOR TRAUMA WAS PERFORMED IN 1959.**
- **THE FIRST AMERICAN SPLENECTOMY WAS PERFORMED IN 1816.**

THE FIRST SUCCESSFUL PARTIAL SPLENECTOMY FOR TRAUMA WAS REPORTED BY FRANCISCUS ROSETTI IN 1590.

- In 1910, William Mayo described splenorrhaphy (Fig. 1.26).
- In the sixteenth century, Paracelsus considered the spleen a superfluous organ. He also advocated excision of the spleen when diseased.
- Vesalius performed splenectomy on many animals without adverse effects. He concluded that the spleen was not necessary to life.
- Adrian Zaccarelli in 1549 performed the first splenectomy.

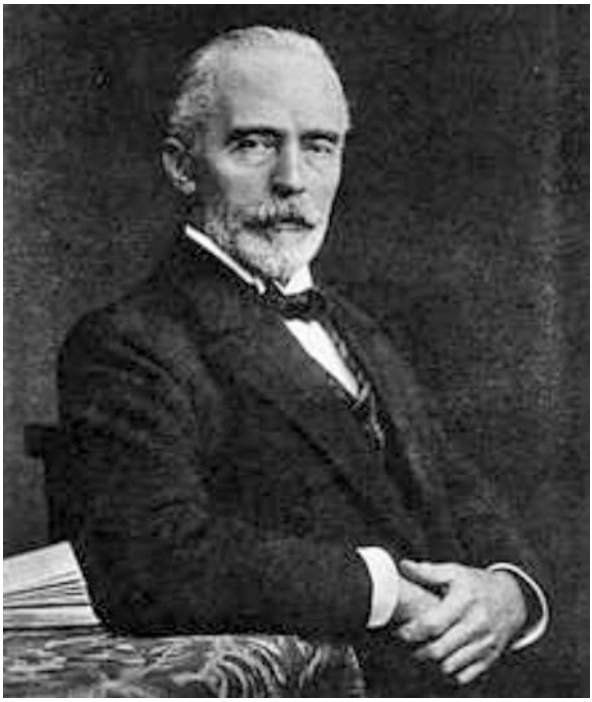

Fig. 1.25 Emil Theodor Kocher (25 August 1841–27 July 1917) was a Swiss physician. In 1909, he received the Nobel Prize in Medicine for his research in the field of physiology, pathology and surgery of the thyroid gland. His mortality following thyroidectomies was less than 1%. He was the first to advocate aseptic techniques in surgery (Science and Tech by Encyclopedia Britanica)

Fig. 1.26 William Worrall Mayo (May 31, 1819—March 6, 1911) was a British-American medical doctor and chemist. He was the founder of the Mayo Clinic (Wikipedia, The free encyclopedia)

  - Leonardo Fioravanti who was assisting Adrian Zaccarelli during the procedure described the operation which was performed in Italy.
  - The patient was a 24-year-old female who suffered from malarial splenomegaly.
  - The spleen weighed 1340 grams.
  - This however was questioned and it has been suggested that an ovarian cystectomy was performed rather than splenectomy.
- The first splenectomy for a tumorous spleen was performed by Quittembaum in 1826. This was done for a 22 years old female who died in the immediate postoperative period.
- In 1881, Franzolini, in Italy, performed splenectomy on a women with aplastic anemia.
- Philippe Charles Ernest Gaucher:
  - In 1855, he described the post-mortem examination of a 32-year-old female with massive splenomegaly.
  - Her spleen weighed more than 4·5 kg.
  - He examined the spleen histologically and described the spleen as being almost normal in shape and color but hard in consistency. The splenic tissue was replaced by by huge epithelial cells, accompanied by interstitial haemorrhages and complete absence of Malpighian corpuscles.
- In 1866, Spencer Wells performed the first splenectomy for splenomegaly in England.
- The first splenectomy for leukemia was performed by Thomas Bryant in 1866.
- In 1911, Micheli in Italy performed splenectomy for severe haemolytic anaemia.
- Kaznelson in 1916 performed splenectomy for severe thrombocytopenia and reported good recovery.
- Lord Berkeley Moynihan (Between 1905 and 1926), published four editions of his book Abdominal operations. In his book, he discussed and explained the indications for splenectomy (Figs. 1.27, 1.28, 1.29, 1.30, and 1.31).
- The first splenectomy described in detail was carried out by Adrian Zaccarelli, in Italy in 1549.
- Delaitre and Maignien in 1991 performed the first total laparoscopic splenectomy.

- **THE FIRST SPLENECTOMY DESCRIBED IN DETAIL WAS CRRIED OUT BY ADRIAN ZACCARELLI IN ITALY IN 1954.**
- **THE FIRST SPLENECTOMY FOR A TUMORUS SPLEEN WAS PERFORMED BY QUITTEMBAUM IN 1826.**
- **SPENCER WELLS IS CREDITED WITH PERFORMING THE FIRST SPLENECTOMY FOR SPLENOMEGALY IN ENGLAND IN 1866 (?LEUKEMIA).**