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Research article - Human anatomy case report

A rare anomaly of the human spleen with nine notches associated with multiple accessory spleens. A case study, hypothesis on origin and review of clinical significance

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Abstract

In humans, the spleen is the body's largest secondary lymphoid organ and filterer of blood. The trabeculated structure of the spleen, which is formed in its early embryonic development, provides its three-dimensional framework designed to remove senescent erythrocytes and eliminate blood-borne microorganisms and/or dubious antigens. At a later date this lobulated framework can develop into notches which usually manifest along its anterior (superior) border. This study addresses the clinical significance and developmental basis of both numerous notches and multiple accessory spleens observed in a male human cadaver. The nine notches were all observed on the anterior and inferior borders, whilst the accessory spleens numbered four, with two localized at the splenic hilum and the other two upon the splenorenal and splenocolic ligaments respectively. In the present study, we propose an aetiological origin for the anomalous multi-notches and accessory spleens, which will provide primary benefit for surgeons and radiologists because of clinical significance.

Key words

Spleen, splenic notch, accessory spleen, anatomy, spleen anomaly

Introduction

The spleen is the largest secondary lymphoid organ in the human body (Borley, 2005). It plays an important role in regulating the number and quality of erythrocytes, eliminating cellular debris from the blood, and responding against antigens and/or virulent pathogens that may have entered the systemic circulation (Mebius and Kraal, 2005). In all mammals the spleen is enclosed by a capsule (Fig. 1) of variable thickness (Onkar and Govardhan, 2013), the capsule in distinct regions ventures into the spleen's parenchyma through trabeculae (Fig. 1). The tissue residing between the capsule and trabeculae forms the cords or pulp (Fig. 1), which by histological appearance can be categorised as red or white pulp and takes upon either storage or defensive functions

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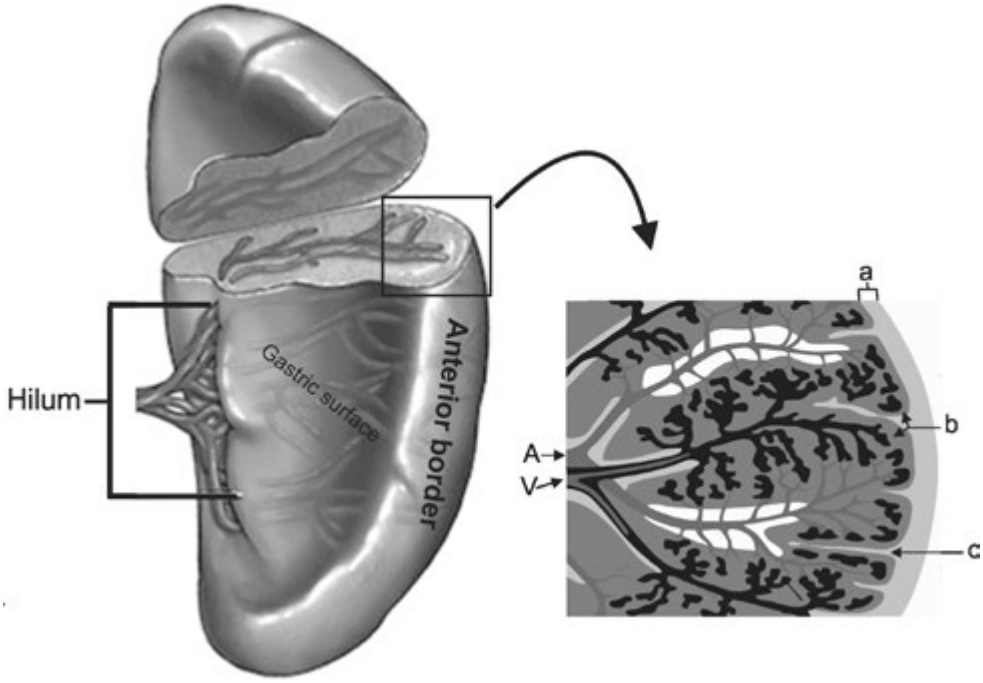

Figure 1 – Schematic drawing of spleen, anterior view. Insert box: cut through anterior border, illustrating the typical histology of the spleen with: a) capsule; b) cords; c) trabecula; A) artery; V) vein.

respectively. The embryonic development of the human spleen is yet to be fully elucidated, nonetheless within the left dorsal mesogastrium around the 5th week of gestation multiple mesenchymal (reticular) cells aggregate and give rise to a lacuna of haematopoietic tissues. By the 8th week, the spleen has a segmented morphology based on arterial lobules, which gradually disappear around week 30, as the spleen develops its lymphoid structures (Balogh and Labadi, 2010). The immune function of the spleen is mediated initially by the migration of B lymphocytes which colonize these lacunae peripherally and then by T lymphocytes centrally around arterioles (Mebius and Kraal, 2005). As this tissue develops, the scant few nodules eventually fuse to form the spleen proper. The points of union of these nodules are believed to be the reason behind the spleen's lobulation and notching on its anterior (superior) border (Coetzee, 1982). However, in some instances, some of these nodules may remain independent of the spleen proper and form accessory spleens (Nayak et al., 2014).

An enlarged spleen can be clinically detected in the left hypochondriac region of the abdomen through palpation. The notch on its anterior border aids in identifying the spleen and differentiating it from other abdominal organs (Coetzee, 1982; Standring, 2008). Therefore, a variation in the number and location of notches may impede the clinical diagnosis of an enlarged spleen (Gandhi et al., 2013). Although traditional anatomical literature has invariably reported that the spleen has only one or two main notches (Standring, 2008), Michels (1942) maintained that the number of

notches may vary from one to six, while more recently Gandhi et al (2013) described a case where one spleen had seven notches.

Islands of healthy, functional splenic tissue located separately from the main spleen are known as accessory spleens; splenules or supranumerary spleens (Freeman et al., 1993), a phenomenon which surprisingly is not that uncommon. Curtis and Movitz (1946) confirmed the presence of accessory spleens in 56 patients out of 174 while Halpert and Gyorkey (1959) revealed 364 accessory spleens in 3000 patients. The presence of accessory spleens has not yet been correlated to any pathological consequences. However, accessory spleens may become highly significant in specific circumstances where their presence could lead to a recurrence in certain haematological conditions such as thalassemia following splenectomy (Curtis and Movitz, 1946; Facon et al., 1992; Budzynski et al., 2003). Conversely, accessory spleens have been shown to be advantageous by providing innate immunity following splenectomy subsequent to trauma (Leemans et al., 1999). Splenectomised patients may be unable to mount appropriate immune responses to bacterial insult, which can be exacerbated when the patient's immune system is already compromised (i.e schistosomiasis) and may be further susceptible to bacterial translocation and sepsis (Lima et al., 2015), thus requiring preoperative vaccinations and ongoing boosters (Dogan et al., 2015; Nived et al., 2015), or lifelong prophylactic antibiotics. Although the number of accessory spleens can vary from 1 to 10, more than 3 accessory spleens are considered very rare (Curtis and Movitz, 1946). Moreover, if accessory spleens are indeed present, they tend to be located in only one anatomical locations such as splenic hilum or pedicle (Curtis and Movitz, 1946). In the present specimen, we report a spleen with nine notches associated with four accessory spleens located in three different anatomical locations rendering this a very rare anomaly and the first to be described in the anatomical literature to the best of the authors' knowledge.

Material and methods

This anomalous spleen was detected during a routine dissection on a formalin fixed male human cadaver (71 years of age). Once the anomaly was identified, the spleen along with its arterial and venous supply was resected, including: the stomach, from the lower oesophageal junction, the duodenum, the short gastric vessels, pancreas, coeliac arterial trunk and mesenteric veins up to the formation of portal vein. All structures were removed out en block for permanent fixation and plastination. All material was made available by the School of Anatomy, Griffith University, in accordance with the Queensland Transplantation and Anatomy Act,1979, and the signed informed consent of the donor.

Results

The spleen was situated under the diaphragm between the stomach and left kidney, posterior to the splenic flexure of the colon. It was intraperitoneal and attached to the stomach and kidney via the gastrosplenic and splenorenal ligaments respectively. The size of the spleen (Fig. 2) was 13 cm in length, 9 cm in width and 5 cm

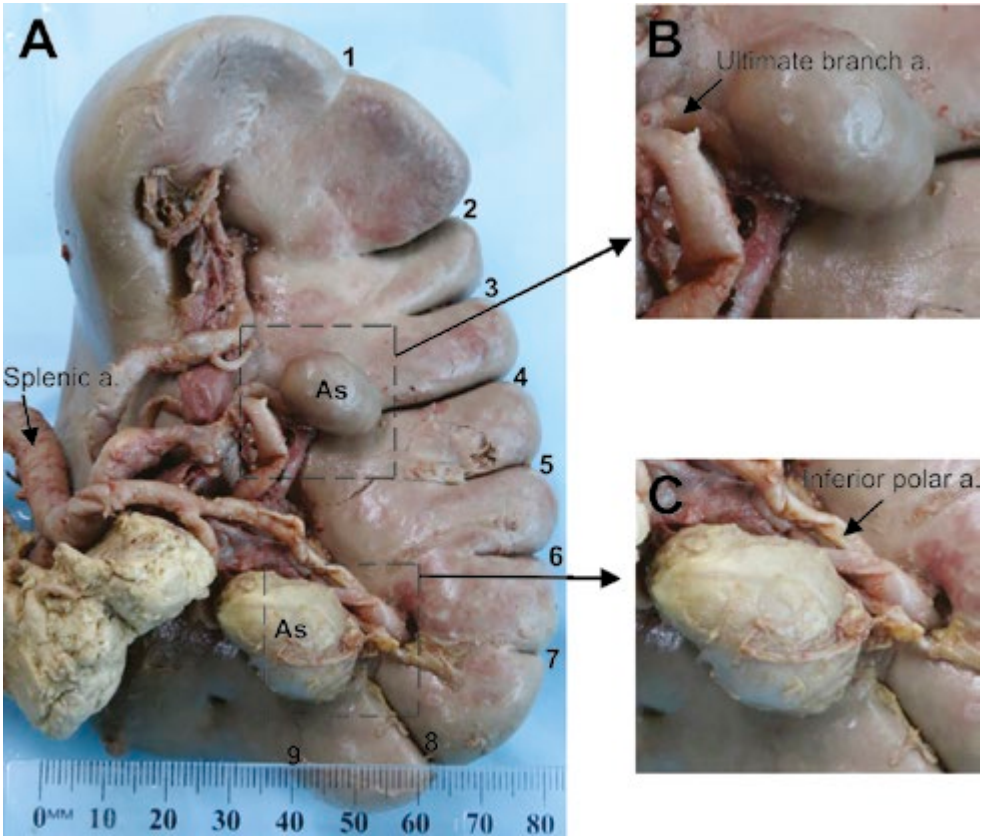

Figure 2 – A) Photograph of adult spleen with nine notches (numbered 1 to 9) along the anterior border and two accessory spleens (As); two other accessory spleens are not shown. Splenic artery trifurcates before entering the hilum, superior to the pancreas. The two accessory spleens are magnified in panels B) and C) to demonstrate the blood vessel supply.

in thickness; the weight was 322.2 grams which is heavier than normally described (Gray, 1897). Along the anterior (superior) border eight notches (Fig. 2A) of variable depth were present at variable distances from each other. Another shallow notch facing the renal surface was present in the inferior border. There were four accessory spleens, two at the splenic hilum (Fig. 2; size 1 cm x 1.5 cm x 1 cm and 2.5 cm x 2 cm x 1.5 cm) which had dedicated arterial twigs (Fig. 2B ultimate branch and Fig. 2C inferior polar arteries) branching out of the main splenic artery (Fig. 2A) and two others (not shown) each of 1.5 cm x 1 cm x 1 cm, one on the splenorenal ligament (arterial supply by superior polar artery) and the other on the splenocolic ligament (arterial supply by inferior polar artery). The arterial supply of the spleen was via a tortuous but direct splenic artery (Fig. 2A), a branch of the coeliac trunk. The splenic artery trifurcated (Fig. 2A) into three main branches: superior, middle (ultimate) and inferior polar arteries. These arteries were paralleled by their respective venous

counterparts, which drained the respective accessory spleens into the splenic vein. The small arterial branches supplying the spleen did not correlate to the individual splenic notches. Other intra-abdominal organs appeared normal in their gross anatomical morphology, and there was no evidence of situs inversus. The cadaver exhibited hypospadias but the heart and lungs showed no gross anomalies.

Discussion

Anatomical significance

The number of notches on the spleen has been a topic of scientific discussion since 1901 whence Parsons (1901) documented it to range from 0 to 7, with 2 notches being most common. Furthermore, he claimed a spleen with 7 notches to be exceptionally rare, reporting only one specimen out of 113. After Parsons (1901), the highest number of notches to be noted in anatomical literature is 7, which was recently reported in India (Gandhi et al., 2013). Prior to that, there have been other reports of splenic notches ranging in number from 0 to 7 (Michels, 1942; Redmond et al., 1989; Das et al., 2008). The present specimen is unique, given that there are 8 notches on the anterior surface and another distinct notch on the inferior surface (Fig. 2).

Accessory spleens are the most common anomaly associated with the spleen and are identified in 10-30% of cadavers at autopsy (Dodds et al., 1990; Freeman et al., 1993; Gayer et al., 2001). Previous evidence from cadaveric studies has demonstrated the occurrence of one, two and three accessory spleens to be 79-86%, 10.5-14% and 1-10.5% respectively (Mortelé et al., 2004; Mendi et al., 2006; Üngör et al., 2007; Unver Dogan et al., 2011). In a large study examining accessory spleens in CT scans, 13% subjects had one or more accessory spleens (Mortelé et al., 2004). Although the presence of more than three accessory spleens has been reported, it is considered a very rare occurrence (Curtis and Movitz, 1946). Moreover, accessory spleens tend to be located around a single anatomical location and thus accessory spleens in multiple anatomical locations are considered exceedingly rare (Curtis and Movitz, 1946). The present specimen had four accessory spleens located in three different locations rendering it unique. Two of the four accessory spleens were situated at the splenic hilum, which is the most common site for accessory spleens (Halpert and Gyorkey, 1959; George et al., 2012), while the other two were located within the splenorenal and splenocolic ligaments respectively.

Previous anatomical literature of human spleens with multiple notches is devoid of any description for associated accessory spleens. Nor have there been reports of accessory spleens described with the concomitance of multiple notches. Thus, this study is exclusive to anatomical literature in that it reports 9 splenic notches associated with 4 accessory spleens.

Basis of multiple notches

The causality of splenic notches or accessory spleens has not been fully explained by phylogenetic studies in literature. Schabadash (1935) investigated a total number of 255 animals consisting of fish, amphibians, reptiles, birds and mammals and did

not outline the phylogenetic significance of the size and form of the spleen in terms of evolution (cited by Michels, 1942). Nevertheless, the hypothesis for the spleen's embryological formation is through the union of multiple splenic mesenchymal masses derived from the dorsal mesogastrium (Thiel and Downey, 1921; Michels, 1942), colonized by progenitor cells of erythroid and myeloid origins (Mebius and Kraal, 2005), and by the differentiation and maturation of a milieu of lymphoid cells (Asma et al., 1986). If that was the case, the presence of multiple splenic notches should appear more frequently in foetuses than in adults, akin to the embryonic development of kidneys (Parsons, 1901). However, it has been established that spleens are less notched in foetuses than in adults (Parsons, 1901). Thus the presence of splenic notches is not adequately explained on an embryological basis.

Alternatively, the number of splenic notches may be explained by food pattern of animals. Studies on carnivore and omnivore species such as cat, lion, dog, fox, otter and seals demonstrated a higher number of notches (on all borders), while herbivore species such as deer, ox, sheep, goat and horse show no notches or, rarely, one notch (Parsons, 1901). This may be explained by the differences in histology of the splenic capsule, where the thickness in humans has been shown to be significantly less when compared to herbivories (cow and goat; Alim et al., 2012); in humans specifically the splenic capsule appears to change with age. Rodrigues and colleagues (1999) showed that within aging humans the elastic fibers within the capsule condense and fragment, thus affecting spleen integrity as one grows older.

As meat contains more immune active substances than plants (Masilamani et al., 2012), it is conceivable that spleens of carnivores experience greater immunological insults than that of herbivores. As the human spleen ages and loses cortical rigidity, while being challenged immunologically, the ensuing immune responses may result in the remodelling of the spleen's extracellular matrix (Mebius and Kraal, 2005), thus causing cleavage points between splenic cords which later give rise to notches (Joo and Kim, 2014). Structural alterations of the spleen have been demonstrated in amphibians when immune responses have been stimulated by viral and bacterial pathogens (Balogh and Labadi, 2010). The spleen is the principal organ of immunity and it is via food that the body is exposed to the largest load of immune active substances. We hypothesise that it may be the food (through immune active substances) along with histological alterations of the spleen's capsule that govern the development of multiple foci of the spleen and may explain the presence of multiple notches in adults. This will occur postnatally when the body is exposed to exogenous antigens in food, which is distinct to the embryo where it would be exposed to negligible immune active material. This is consistent with the observation of foetal spleen having less pronounced notches than that of adults (Parsons, 1901).

Clinical significance

Identifying splenomegaly is extremely important in clinical practice when diagnosing diseases. Variations in the size of the spleen, particularly an enlargement, usually reflect an underlying pathology of either the reticuloendothelial system or the lymphoid system (Kumar et al., 2009; Rayhan et al., 2011. Even though the splenic size is routinely gauged ultrasonographically (Lamb et al., 2002), it is com-

monly through clinical palpation that splenomegaly is diagnosed. When examining the spleen clinically, one of the most characteristic findings is the splenic notch which distinguishes it from other organs in the left hypochondriac region. Therefore multiple notches may lead to a false positive clinical diagnosis of splenomegaly (Gandhi et al., 2013). Furthermore, when there are multiple notches present in the anterior border, these lobulations may easily be mistaken for neoplasms of the kidney and/or adrenal gland radiologically. Moreover, in patients with blunt abdominal trauma to the left hypochondrium, the presence of multiple deep and sharp notches on the spleen may inaccurately be misinterpreted as splenic lacerations, possibly resulting in an unnecessary exploratory laparotomy (Gayer et al., 2006; Joo and Kim, 2014).

Accessory spleens are usually asymptomatic. However, if present, they can be mistaken for neoplasms or lymph node enlargements in organs such as the pancreas, kidney, or adrenal gland (Servais et al., 2008; George et al., 2012). Cognisance of accessory spleens by health professionals may facilitate correct diagnosis and avoid unnecessary invasive interventions (Zhang and Zhang, 2011). Rarely, accessory spleens may present with abdominal pain if they undergo torsion (Wacha et al., 2002; Grinbaum et al., 2006).

Where the spleen necessitates removal for therapeutic interventions, such as idiopathic thrombocytopaenic purpura, accessory spleens may remain inadvertently after surgery and thus impede complete resolution (Facon et al., 1992; Budzynski et al., 2003). This is because accessory spleens can also be involved in any condition involving the spleen (Joo and Kim, 2014). Therefore, the European Association of Endoscopic Surgeons has recommended that accessory spleens be investigated routinely during laparoscopic surgery for splenectomy especially in autoimmune haematological disorders (Rudowski, 1985; Gigot et al., 1998; Unver Dogan et al., 2011).

The presence of multiple spleens is associated with congenital anomalies of other visceral organs and some syndromes (Rose et al., 1975; Gayer et al., 2006; Tawfik et al., 2013). Heterotaxy syndrome is one such syndrome that is characterized by abnormal arrangement of organs and vessels across left right axis of the body (Strickland et al., 2008). In this syndrome, polysplenia is associated with bilateral left sidedness (Gayer et al., 2006) such as bilateral bilobed lungs (Peoples et al., 1983), inferior vena cava obstruction with azygous continuation (Gayer et al., 1999), none of which was seen in the present specimen. Conversely however, a favourable outcome of having accessory spleens has been demonstrated in patients who had undergone emergency splenectomy, where functional accessory spleens accommodated some humoral immunity (Leemans et al., 1999).

Conclusions

The present study reports a unique specimen with a variation in splenic anatomy, including the highest number of splenic notches reported in the known anatomical literature. It was also accompanied by multiple accessory spleens in three different anatomical locations. A novel hypothesis on the occurrence of multiple splenic notches based on exposure to immunologically active substances after birth is proposed.

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