



Gross Anatomical, Radiographic and Ultra-structural Identification of Splenic Vasculature in some Ruminants (Camel, Buffalo Calf, Sheep and Goat)

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Abstract

The current investigation was carried out on the spleens of camel, buffalo calf, sheep and goat. The number of spleens used for each species was sixteen spleens divided as the following: five spleens for latex technique, five spleens for corrosion cast, five spleens for radiographic technique and one spleen for histological and scanning electron microscopy. The spleen of camel has two hilus, four segments, two splenic arteries and two splenic veins while the other species having only one small hilus. There was no arterial anastomosis in the spleen of camel only resulting in the presence of arterial segmentation but there was a venous connection between the dorsal and intermediate segments in camel resulting in the absence of venous segmentation between these segments while the other species studied having an obvious arterial anastomosis and absence of the venous one. The aim of this study is to illustrate the vascular segmentation of spleen through the vascular anastomosis which is of great importance in variable surgical applications as sample biopsy, partial or complete removal of spleen and localization of vascular emboli and to identify by using the aid of scanning electron microscope, the sinusal or non-sinusal types of spleens.

Keywords: Spleen, Ruminants, Radiography, Scanning, Vascular segmentation, Sinusal type.

Introduction

The role of the spleen as a haemopoietic and immunologic organ, especially for meat producing animals as ruminants, gives it a great interest of many investigators in anatomy and surgery. However, for defense, spleen is the major secondary lymphatic organ structurally specialized to filter, retain and deal with the blood borne pathogens. In addition, it has the ability to add to the erythrocyte and granulocyte population and can be acting as a reservoir of red blood cells during periods of unusual demand (Pabst, 1993 and Onkar and Govardhan, 2013) in camel. Histologically, the spleen classified by many authors into defensive and storage types (Banks, 1993) according to trabeculae and smooth muscle

fibers, others into sinusal and non-sinusal types (Dellman and Brown, 1981) according to the type of post capillary vessels. There are sinusal type spleens, e.g. in horses, dogs and pigs (Brown and Dellmann, 1976), man, rats and rabbits (Blue and Weiss, 1981b) and non-sinusal types, e.g. in cats, ruminants (Brown and Dellmann, 1976) and mice (Blue and Weiss, 1981a) while (Bareedy et al., 1982 and Zidan et al., 2000) confirmed that the camel spleen classified as of a sinusal type.

In this our investigation, we try to understand and avoiding the generally mis-talking a word of "sinusal or non-sinusal" spleens on all ruminants, so, this study

purposed to strictly knowing whose of studied ruminants of sinusal and whose of non-sinusal type spleens, in addition to anatomical segmentation and parenchymal distribution of splenic blood vessels which is of great importance in surgical localization of vascular emboli, sample biopsy or for partial and complete removal of spleen.

Materials and Methods

The present investigation was conducted on sixty four spleens of two large ruminants; the camel and buffalo calf and two small ruminants; the sheep and goat, obtaining sixteen spleens for each individual animal. The specimens were obtained fresh after slaughtering from the abattoir near Giza governorate.

Three different techniques were used in our investigation; colored latex injection, corrosion cast and radiography of the splenic vasculature through using five spleens from each species for each technique and one spleen for microscopic examination.

Each spleen was perfused with normal saline through splenic artery to remove blood from blood vessels. Later the spleen was infused with 10% buffered formalin through splenic artery and splenic vein was then ligated. The splenic artery and vein were exposed and cannulated using a suitable cannula or catheter according to the size of vessels.

For latex technique, injecting suitable amount of **60% gum milk latex** (diluted with ammonia) which colored red for the artery and blue for the vein with Rotring® ink.

For corrosion cast technique, using (**KEMAPOXY 150 2A/1B**); a transparent chemical mixture of thin (B) and thick (A) reagents obtained from chemical modern building (CMB) and mixed together in ratio of 2A:1B then injected immediately before solidification after adding the color.

For radiography, we used two radio-opaque material; few milliliters of **urograffin** (75%) diluted 3:1 with water (**El-Zomor, 1991**) then radiographed immediately using 52 KVP 48 MA, 0.5 second and FFD70 cm. others were injected with **red lead oxide** and **turpentine oil** (**Hagras, 1982**) then radiographed immediately using 55 KVP 30-70 MA, 0.5 second and FFD70 cm.

For scanning electron microscopy (SEM), small pieces of 1cm³ from each spleen at different regions were taken fresh after slaughter and put in a fixative containing 2.5% glutaraldehyde in 0.1 M phosphate buffer and adjusted to pH 7.4 then dehydrated in ascending concentrations of ethanol using automatic tissue processor (**Leica EM TP**). The dried specimens were fixed on a metal stub with conductive paste holding the fractured surface upward. In order to obtain sufficient electrical conductivity and yield of secondary electrons, the fractured surface of the specimen was doubly coated by vacuum evaporated carbon and ion-sputtered gold (**SPI-module-sputter coater**). The specimens were rotated and tilted during the evaporation. All the specimens were examined by scanning electron microscopy (**JEOLJSM-5500 LV**) JEOL Ltd, Japan, in 18 micrographs by using low vacuum mode at the **Regional Center of Mycology and Biotechnology (RCMB), Al-Azhar University, Cairo, Egypt**.

The obtained results were photographed using a digital photo camera **Nikon COOLPIX L310 14.1 Megapixels** in 10 photos. The nomenclature used was that recommended by the Nomina Anatomica Veterinaria, 5th edition by (**Frewein and Habel, 2012**) as well as the previous literatures.

Results and Discussion

Anatomical Findings:

The current investigation revealed that the spleen of camel was C-shaped with a thin serrated cranial border (**fig.1a/h**) and a thick wide fatty caudal border (**fig.1a/i**) and blunt dorsal and ventral extremities, the thickness was not uniform, appeared thick at midpoint and hilus but thin at edges. The surface of the camel spleen was rough. It extending from the caudodorsal part of rumen to the caudal end of left kidney and maintained on a ligamentous system; the reno-splenic ligament (**fig.1a/e**) and the splenopancreatic ligament (**fig.1a/f**), the latter being attached to the caudal thick margin of the spleen. The spleen is also strongly related to rumen by means of a rather short ligament, the gastrosplenic ligament. A result which was similar to that recorded by (**Bennoune and Al-Samarrae, 2012** and **Maina et al., 2014**) in camel.

Our results were in agreement with that found by (Maina et al., 2014) and (Usende et al., 2014) that the camel spleen was dark brown in color contrasting the bright red color in Nigeria indigenous pig and light brown colour in West African dwarf goats. They also added that the C-shaped and blunt edge spleen of camel also contrast the slipper-shaped of that pig, quadrangular-shaped of that goat, tongue-shaped of dog by (Onkar and Govardhan, 2013), a falciform-shape of horse by (FozFilho et al., 2013) and triangular comma-shaped of the Bangladesh horse by (Alam et al., 2005).

The spleen of camel in this study has a length of 22.5 to 31.5 cm, a width in the middle of 8.5 to 14 cm and a maximum thickness from 1.25 to 2.5 cm. a result which not simulates that recorded by (Bennoune and Al-Samarrae, 2012) that the camel spleen has a length of 17.5 to 28 cm, a width in the middle of 6.25 to 12 cm and a maximum thickness from 1.84 to 4.96 cm. and also differed than that reported by (Maina et al., 2014) that the camel spleen weighing of 0.425 ± 0.04 kg., while in our results weighing about 0.837 ± 0.03 kg.

The splenic arterial vasculature of the camels investigated was ensured by two branches of the splenic artery; the body and the ventral extremity were vascularized by the first branch of the splenic artery (fig.1a/1). The second branch (fig.1a/7) ensured the irrigation of the dorsal end of the spleen. The hilum of the spleen was of broad type, the arteries and their branches penetrated at different points of the dorsal end to the middle of the caudal margin with the presence of an enough fatty tissue that completely surrounds the blood vessels.

Our observations revealed that the arterial vascular pattern of the camel spleen throughout its ventral two thirds was perpendicular to its long axis while being parallel to the same axis in the dorsal third of the spleen. In addition, Gupta et al. (1978a through 1979) in the buffalo, dog, goat and sheep respectively and FozFilho et al. (2013) in horse reported that the vascular pattern was parallel to long axis of the spleen throughout the entire length of the organ. Moreover, Gupta et al. also described two to three arterial segments in the spleen of buffalo and goat and only two in that of sheep and dog. Finally, the camel spleen revealed cranial, middle and caudal arterial segments by Abu-Zaid et al. (1985) in camel while Osman et al. (1981) in ox, sheep, camel, pig and dog; simulate our results by describing them as dorsal (fig.1b/a),

intermediate (fig.1a/b) and ventral (fig.1a/d) arterial segments.

All the previous literatures agreed that the arterial supply of the camel spleen divided according to its size and area of distribution into major or "first" and minor or "second" splenic arteries. The major splenic artery originating from the celiac trunk, it was larger than the minor one and early gives rise to main two branches (fig.1a/3,4) which running in the splenopancreatic fold (fig.1a/f) and penetrate into the spleen at the level of the caudal thick margin, the splenic hilus.

The major splenic artery (fig.1a/1) was responsible for blood irrigation of more than two third of the spleen, Then proceeds caudally and at the middle of pancreas (fig.1a/g), divided into two primary branches, the cranial (fig.1a/3) of which proceeds toward the middle third of the spleen to which it gives 3-4 smaller branches (fig.1a/9). The caudal one (fig.1a/4) precedes caudally toward the posterior third of the spleen to which it detaches 5-6 rami before it gains the posterior splenic hilus. The primary branches of this branch irrigate a well-defined segment without anastomosis with the other branches; the segments were separated by relatively avascular planes. A result which was in agreement with that found by (Abu-Zaid et al., 1985, Bennoune and Al-Samarrae, 2012, and Maina et al., 2014) in camel and (FozFilho et al., 2013) in horse.

Our results were in accordance with that found by Abu-Zaid et al. (1985) in camel that the entrance site of the cranial branch of the major splenic artery was variable; it might be in front of the dorsal end or between the dorsal end and middle of the caudal margin and supporting the intermediate segment of spleen. The caudal branch was located just after the penetration of cranial one, where it gives two secondary dorsal and ventral arteries, supporting – from ventral to dorsal- two splenic segments; the ventral segment and the additional segment (fig.1a and 4b/9'). On the other hand, our results were disagreed with Bennoune and Al-Samarrae (2012) who described that the additional segment, which located between the ventral and the intermediate segments, irrigated by an artery from the cranial branch of the major splenic artery and not from the caudal one.

Figure Legends

1. Major (first) splenic artery.	a. Proximal splenic segment.
2. Major (first) splenic vein.	b. Intermediate splenic segment.
3. Cranial branch of 1.	c. Additional splenic segment.
4. Caudal branch of 1.	d. Distal splenic segment.
5. Cranial branch of 2.	e. Renosplenic ligament.
6. Caudal branch of 2.	f. Pancreaticosplenic ligament.
7. Minor (second) splenic artery.	g. Pancreas.
8. Minor (second) splenic vein.	h. Cranial border of spleen.
9. Primary branches of 1.	i. Caudal border of spleen (Hilus).
10. Primary branches of 2.	j. Peritoneal reflection.
11. Primary branches of 7.	
12. Primary branches of 8.	
13. Secondary splenic arteries.	
14. Tertiary splenic arteries.	
15. Pancreatic artery.	
16. Pancreatic vein.	
17. Artery of renal capsule.	
18. Splenic nerve.	
19. Splenic artery of (calf-sheep-goat).	
20. Splenic vein of (calf-sheep-goat).	
21. Dorsal branch of 19.	
22. Intermediate branch of 19.	
23. Ventral branch of 19.	
24. Dorsal branch of 20.	
25. Intermediate branch of 20.	
26. Ventral branch of 20.	
27. Dorsal & ventral divisions of 21.	
28. Dorsal & ventral divisions of 22.	
29. Dorsal & ventral divisions of 24.	
30. Cranial branches of 23.	
31. Middle branch of 23.	
32. Caudal branches of 23.	
33. Tertiary division of splenic artery.	
34. Hilar arterial branches.	
35. Hilar venous branches.	

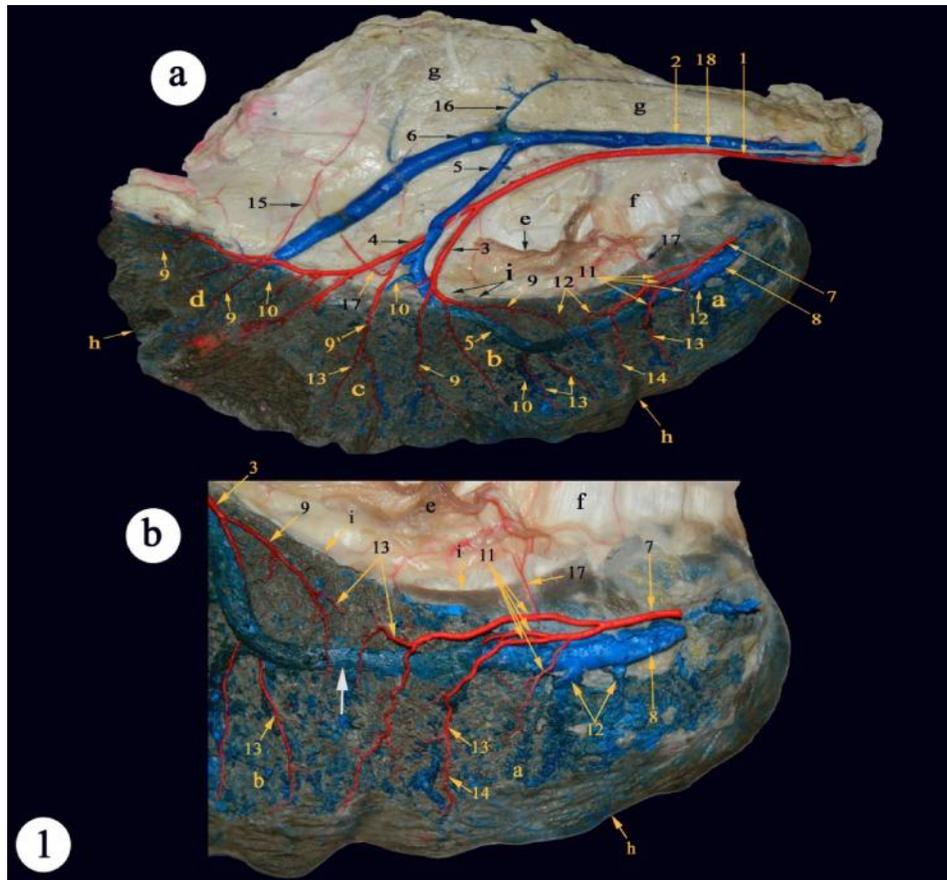


Fig. (1). Gross anatomical photographs of camel spleen showing the splenic vasculatures. (a) Spleen and pancreas as a whole. (b) Dorsal splenic segment.

The present findings were simulate the findings of **Abu-Zaid et al. (1985)** in camel that the minor splenic artery (**fig.1b/7**) was smaller and shorter than the major one (**fig.1a/1**) reaching the anterior splenic hilus where it divided into 3-4 small branches (**fig.1b/11**) to the anterior third of the spleen and responsible for irrigation of the dorsal segment (**fig.1b/a**). This artery determined a single segment independent of the other segments resulting from the major splenic artery. However, the vascular pattern of these branches was parallel to the long axis of the spleen. A result which not recorded by **Bennoune and Al-Samarrae (2012)** in their results in camel spleen. In addition, **Abu-Zaid et al. (1985)** also added that in 20% of cases, an accessory splenic artery originating from the right ruminal artery participated in the vascularization of the dorsal segment of the spleen. A result which not observed in any of our specimens.

Our investigations were similar to that cited by **Abu-Zaid et al. (1985)** who reported that the intrasplenic

distribution of the arteries in camel showed no anastomoses between the main radicles which was very clear in the radiographic specimen (**fig.7a**), this indicated the arterial segmentation in camels, a fact which agreed with the findings of **Bolbol et al. (1985)** in the camel and **El Zomor (1985)** in the donkey, calf and goat. Such distribution might be of help in partial splenectomy in the camel.

Our results illustrated that the venous return of the camel spleen was carried out via the major and minor splenic veins due to the presence of two hilus. The major splenic vein (**fig.1a** and **4a/2**) drained the posterior two third of the spleen via its two main radicles (**fig.1a/5,6**), each of which formed by the confluence of 2-3 small veins (**fig.1a/10**). The minor splenic vein (**fig.1b** and **4a/8**) drained the anterior third of the spleen through one main radicle connected cranially with the right ruminal vein and caudally with the cranial radicle of major splenic vein (**fig.1b/white arrow**). While **Abu-Zaid et al. (1985)** in camel

reported that the minor vein drained the anterior third of the spleen through two main radicles and also added that in 20% of cases, the minor splenic vein joined the major one instead of its union with the right ruminal vein and thus, a single splenic vein is formed. A result which not simulate our observations.

The spleen of buffalo calf in the current study has an average length of 34.5 to 38.5 cm and a width of 12.5 to 14.5 cm while the thickness at the middle part of 2 to 2.5 cm and weighing fresh about 0.784 ± 0.05 kg. It has a bright purple color, elongated elliptical in shape with dorsal broad border and narrow rounded ventral end while the caudal border was convex and slightly higher than the concave cranial border which contained the hilus in its proximal point.

Our results revealed that the splenic artery of buffalo calf, before entering the splenic hilus, divided into three primary branches, dorsal (fig.2a/21), intermediate (fig.2a/22) and ventral (fig.2a/23), each supplying the corresponding area of the spleen. The dorsal branch extended caudodorsally in the parenchyma for about 2-3 cm and bifurcated into two branches (fig.2a/27) which subdivided- in a tree-like manner - within the dorsal third of the organ. The intermediate branch divided as the dorsal one

supplying the middle segment while the ventral branch considered as the direct continuation of the splenic artery. These results differed than that found by (FozFilho et al., 2013) in horse where the splenic artery had no extra parenchymal division.

Through its intrasplenic course, our investigations assumed that the ventral branch of the splenic artery (fig.2a/23) in the buffalo calf curved somewhat caudally near the junction of the middle and distal thirds of the organ to terminate at the ventral extremity with the presence of arterial anastomosis either between the branches of the same artery or between branches of the primary splenic arteries (fig.2a,b and 8a/white arrows). These findings were similar to that found by Ismet Takci (2009) in cattle. However, Osman et al. (1987) in buffalo calf reported the division of splenic artery after gaining the splenic hilus, into two primary branches, dorsal and ventral only. On the same manner, Gupta et al. (1978) in buffalo reported that out of 44 specimens, in 41 (93.18%) the splenic artery bifurcated into 2 primary branches; a small dorsal and a large ventral and in 3 specimens (6.82%) it trifurcated into 3 primary branches; a small dorsal, an intermediate and a large ventral without any anastomosis.

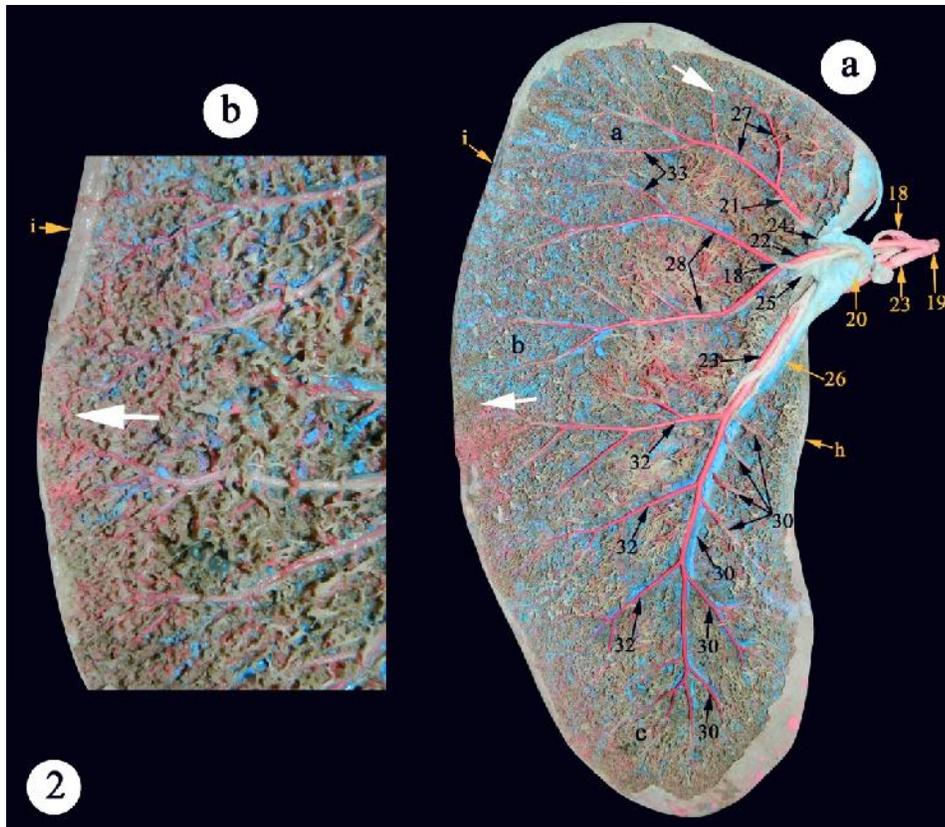


Fig. (2). Gross anatomical photographs of buffalo calf spleen showing the splenic vasculatures. (a) Visceral surface of spleen as a whole. (b) Magnified part showing arterial anastomosis.

Our observations were in agreement with **Osman et al. (1987)** in buffalo calf, that along the course of the ventral splenic branch, it gave off cranial and caudal branches. The cranial branches (**fig.2a/30**) ranged from 6-10 in number extending in a cranioventral direction to ramify within the corresponding part of the organ. They increased in length as traced ventrally. The caudal branches (**fig.2a/32**) ranged from 6-8 in numbers and supply the greater caudal part of the spleen. They extended mostly parallel to each other obliquely in a caudoventral direction.

The splenic vein (**fig.2a/20**) in buffalo calf entered the hilus of the organ caudal to the artery (**fig.2a** and **5b/19**). The primary branches of the splenic vein (**fig.2a** and **5a,b/24,25,26**) were accompanied to the artery, while their further ramifications did not follow the distribution pattern of the artery. **Osman et al. (1987)** also added that, a large number of arterial, venous and arterio-venous anastomoses had been observed in different parts of the organ revealing that the partial splenectomy was not recommended in buffalo calves. A result which simulate our observations in the terminal arteries (**fig.2a,b** and **8a/white arrows**) in this study.

Osman et al. (1987) in buffalo calf had cited that, simulating the results of **Happich (1961)** in sheep; **Wilkens and Munster (1976)** in cattle; and **Osman et al. (1985)** in sheep and cattle, their work revealed the division of the splenic vessels inside the organ. On the other hand, **Bolbol et al. (1985)** in the buffalo and **Ismet Takci (2009)** in cattle mentioned that the splenic vessels divided into cranial and caudal branches 5-10 cm before the splenic hilus. A result which had been revealed by the present work in buffalo calves. On this basis, they concluded the possibility of partial splenectomy in the buffalo calf.

The spleen of sheep in the current study has an average length of 12.5 to 14.5 cm and a width - at the middle of both the cranial and caudal borders - of 5.5 to 7 cm while the thickness at the middle part of 0.75 to 1.22 cm and weighing fresh about 0.328 ± 0.04 kg. It has a purple blue color, triangular in shape with a wide broad dorsal border and a pointed ventral apex, cranial convex border directed caudoventrally and nearly straight caudal border with some corrugations. The splenic hilus appeared as small rounded area at the cranial border just below the proximal extremity by 1.5-2 cm.

Our investigations revealed that the splenic artery (**fig.3a,6a** and **9a/19**) of the sheep divided into two primary divisions, a dorsal (**fig.3a,6a** and **9a/21**) and a ventral (**fig.3a,6a** and **9a/23**), just after its entrance into the splenic hilum, located near the cranial angle of the spleen, with the presence of hilar small branches 1-2 cm (**fig.9a/34**) before its division. A result which did not recorded by **Gupta et al. (1979)** in sheep.

The current study illustrated that the dorsal primary division (**fig.3a** and **9a/21**) of splenic artery of sheep directed toward the dorsal broad extremity of the sheep spleen giving up and down tree-like small branches till the middle of dorsal extremity where it divided into two secondary branches (**fig.3a** and **9a/27**) while the ventral primary division (**fig.3a** and **9a/23**) directed oblique caudoventrally parallel to the cranial border of spleen and at the half distance divided into two to three secondary branches; cranial (**fig.3a** and **9a/30**), middle (**fig.3a** and **9a/31**) and caudal divisions (**fig.3a** and **9a/32**).

Our results were disagreed with that found by **Gupta et al. (1979)** in sheep, who reported that in 28 spleens of 40 (70 %) the splenic artery divided into right and left primary divisions. In 1 case (2.5 %) it divided into parietal and visceral primary divisions in which the branches of visceral division alone supplied the cranial half of the visceral surface of the spleen; the caudal half of this surface received branches from both divisions. While in 11 specimens (27.5 %) the artery ramified irregularly after its entrance into the splenic hilus, and no arterial segmentation was discernible.

The terminal arterial branches between the two primary divisions or of the same division in the present study in sheep specimens, showed an obvious anastomosis (**fig.3a/white arrow**) especially in the radiographic pictures and presence of hilar branches (**fig.9a/34**) at the hilus in three specimens out of five. A result which did not reported by **Gupta et al. (1979)** in sheep who added that the avascular plane being oblique to the long axis of the spleen as well as **Bennoune and Al-Samarrae (2012)** in camel who cited that the spleen of dog, sheep and goat was formed of segments defined by an independent vascularization characterized by the absence of anastomoses between the adjacent arteries although there absence of visible anatomical separations or partitions. A results which did not match our investigations.

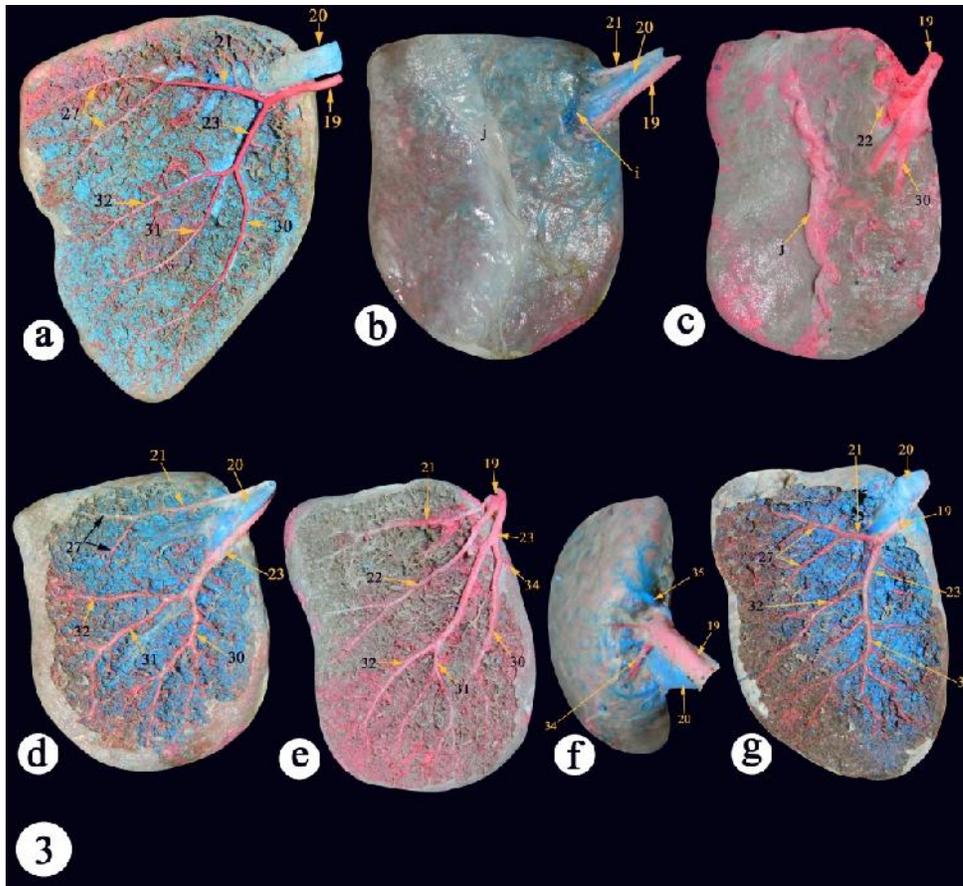


Fig. (3). Gross anatomical photographs of sheep and goat spleens showing the splenic vasculatures.
 (a) Spleen of sheep.(b),(c),(d),(e),(f),(g)Spleens of goat.

Gupta et al. (1979) had cited that both **Clausen (1958)** and **Gutierrez-Cubillos (1969)** in sheep reported the presence of two to four arterial segments in the human spleen. However, in their study of the human spleen (**Gupta et al., 1976**) no specimen showed more than three segments. They also added that the variation in the position of the arterial segments in different species was perhaps associated with the position of the hilus and absence of the splenic arterial segmentation was more common in sheep than in goat and dog. In addition, all human and buffalo spleens examined showed segmentation. A results which did not simulate our findings where the arterial anastomosis (**fig.9a/white arrow**) was very clear in sheep and this resulted in the absence of arterial segmentation.

The spleen of goat in the current study has an average length of 6.5 to 7.5 cm and a width of 3.5 to 5 cm while the thickness at the middle part of 0.85 to 1.5 cm

and weighing fresh about 0.195 ± 0.02 kg. It has a dark bluish brown color, rectangular in shape with rounded borders. The splenic hilus appeared as small rounded area at the cranial border.

In agreement with **Happich (1961)** in sheep; **Wilkins and Munster (1981)** in cattle; **Osman, El-Ayat and George (1981)** in sheep and cattle; **El-Zomor (1985)** in goat and calves; **Dyce, Sack and Wensing (1987)** in ruminants; in addition to **Osman et al. (1987)** in the buffalo calves, the splenic vessels passed undivided through a confined hilus and then divided inside the splenic parenchyma. Otherwise, the splenic artery was divided extrasplenic 2-3 cm before reaching the splenic hilus in 25% of the examined specimens where it detached smaller branches at the region of hilus. This was in accordance with our results and those given by **Bolbol et al. (1985)** in the buffalo and **Ismet Takci (2009)** in cattle.

In agreement with **Gupta et al. (1978a,b)** in the buffalo and dog, **El-Zomor (1985)** in goat and **Osman et al. (1987)** in the buffalo calves, the splenic artery of goat (**fig.3e, 3g/19**) was divided into two main branches, dorsal(**fig.3d,3e** and **3g/21**) and ventral(**fig.3d,3e** and **3g/23**). While, **Gupta et al. (1978c and 1979)** in the goat and sheep respectively, named these two branches as right and left.

Our results revealed that the splenic artery of goat in 11 specimens of 15 was divided before reaching the hilus(**fig.3b,3d** and **3c/19**) by about 1-2 cm into two main primary dorsal and ventral branches inclosing the splenic vein(**fig.3b/20**) in-between. While it was undivided in 4 specimens(**fig.3g/19**) entering the small rounded splenic hilus on the visceral surface close to the craniodorsal angle of the spleen. The artery proceeded caudoventrally for about 2-3 cm, before its splitting into a small dorsal branch (**fig.3d,3e** and **3g/21**) and a large ventral one(**fig.3d,3e** and **3g/23**). In addition, **Wally and Gad (1998)** in goat reported that only in two specimens (25%), the division of the splenic artery occurred extraparenchymal 2-3 cm before reaching the hilus.

In all our specimens in whom the splenic artery either divided intra or extra splenic hilus, there were capsular branches (**fig.3e** and **3f/34**) arborizing at the rounded region of the hilus. Otherwise, the intra parenchymal part of splenic artery showed only in two specimens, a hilar branch (**fig.6b/3 4**) originating before its division into primary dorsal and ventral branches, a result which similar to that found by **Ismet Takci (2009)** in cattle. While **Gupta et al. (1978)** in goat confirmed that in 37specimens of 50 (74%), the splenic artery divided into two main divisions only, right and left, but in 5 specimens (10%), it gave a hilar branch then divided into right and left branches.

Gupta et al. (1978) observed that in 8 specimens (16%) of goat spleens, the splenic artery, after its entrance into the spleen, ramified irregularly. Thus no arterial segmentation was observed in these specimens. A result which was recorded only in 1 case in the current study revealing that the splenic artery divided extra parenchymal into 4 branches(**fig.3c/19**), running 3 cm on the outer surface then directed into the inside of the spleen which illustrated as dorsal(**fig.3e/21**), intermediate(**fig.3e/22**)and large ventral (**fig.3e/23**)divisions. The ventral primary division giving the cranial branch (**fig.3e/30**) earlier then continued toward the caudoventral angle to divide into middle(**fig.3e/31**) and caudal branches (**fig.3e/32**).

Our observations in the current study were similar to that reported by **Gupta et al. (1978)**and **Wally and Gad (1998)** in goat that the dorsal branch(**fig.3d/21**) of the splenic artery was relatively small; it preceded caudodorsally parallel to the dorsal basal border of the spleen towards its caudal border, where it divided into two smaller branches(**fig.3d/27**) which nourished the caudal angle. Moreover, along its course it released 3-6 dorsal and 4-7 ventral fine branches which were distributed to the dorsal third of the spleen.

Our results observed that only in two cases of 15 specimens, there was an artery originated at the midpoint of the ventral branch of splenic artery and before its division into two secondary branches(**fig.6b** and **6c/22**) that might be considered as a supportive artery with the dorsal branch nourishing the proximal half of the goat spleen. In addition, another one specimen showing the presence of only two divisions of the primary ventral division, cranial (**fig.3g/30**) and caudal branches(**fig.3g/32**) and absence of middle branch which was compensated by small branches from the cranial one. A result which not recorded by **Gupta et al. (1978)** or **Wally and Gad (1998)** in goat.

The ventral branch was a large vessel and could be considered as the direct continuation of the splenic artery in goat. It preceded caudoventrally inside the splenic parenchyma towards the ventral extremity. Along its course, it gave small tree-like branches directed cranial and caudal into the splenic parenchyma and after a distance of 1.5-3 cm become divided into two secondary branches each of them giving about 6-8 cranial branches and 5-7 caudal branches supplying the middle and ventral parts of the spleen(**Wally and Gad, 1998**). A results which were in accordance with our observations except that we found the division of the ventral branch into three smaller branches in the majority of cases and only one case which recorded two branches of the ventral division(**fig.3g/30,32**).

There was numerous fine anastomoses observed between the dorsal and ventral branches (**fig.10a/white arrows**) of the splenic artery and, so, it was difficult to divide the spleen of the goat into two independent arterial segments. A result which was recorded by **Osman et al. (1987)** in buffalo calves and **Wally and Gad (1998)** in goat and similar to our investigations but not recorded by **Gupta et al. (1978c)** in goat.

A segmental arrangement of the splenic vein has been demonstrated in man (Fuld and Irwin, 1954) and in dogs (Goldewski, Pelissier and Emberger, 1957). Such a finding was demonstrated in our examined specimens of "buffalo calve, sheep and goat" where the splenic vein follow the distribution pattern of the artery in some specimens (fig.5a,5b,6d,6f,8b,9b and

10b) and distributed irregularly in others (fig.6e/20) but without any venous anastomosis in these species. On the other hand, there was a venous connection between the dorsal and middle segments in the spleen of camel (fig.1b and 7b/white arrows) which indicate that there is no venous segmentation in camel but the arterial one is confirmed in the current study.

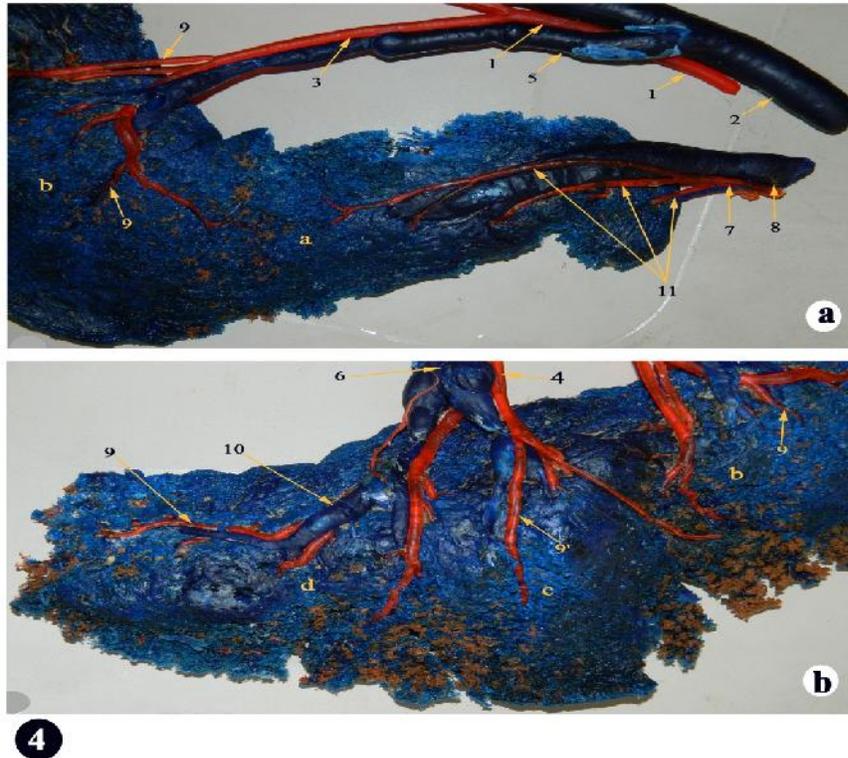


Fig. (4). Corrosion cast photographs of camel spleen showing the distribution of splenic vasculatures. (a) Dorsal splenic segment. (b) Intermediate, additional and ventral segments.

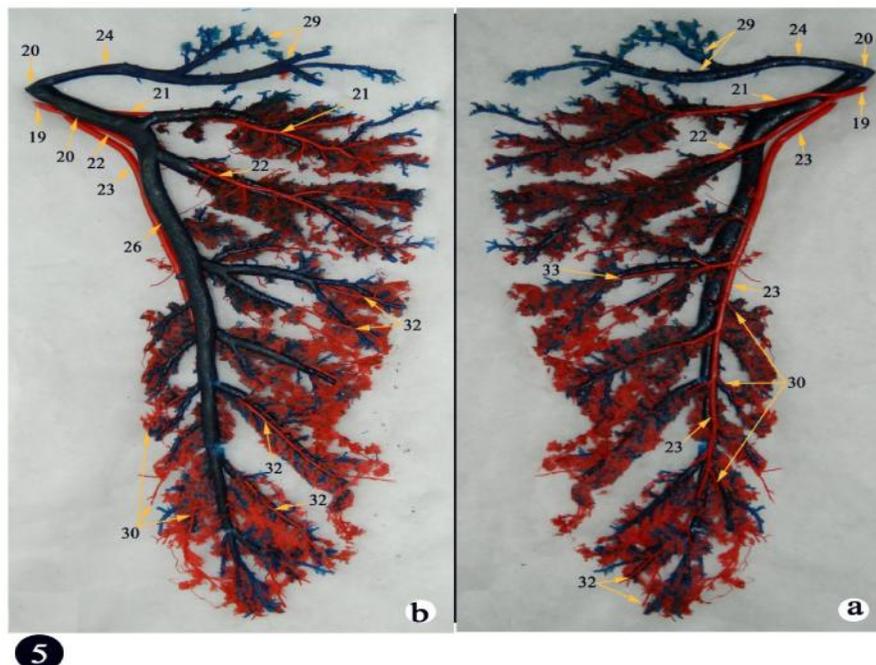


Fig. (5). Corrosion cast photographs of buffalo calf spleen showing the distribution of splenic vasculatures. (a) Visceral view. (b) Parietal view.

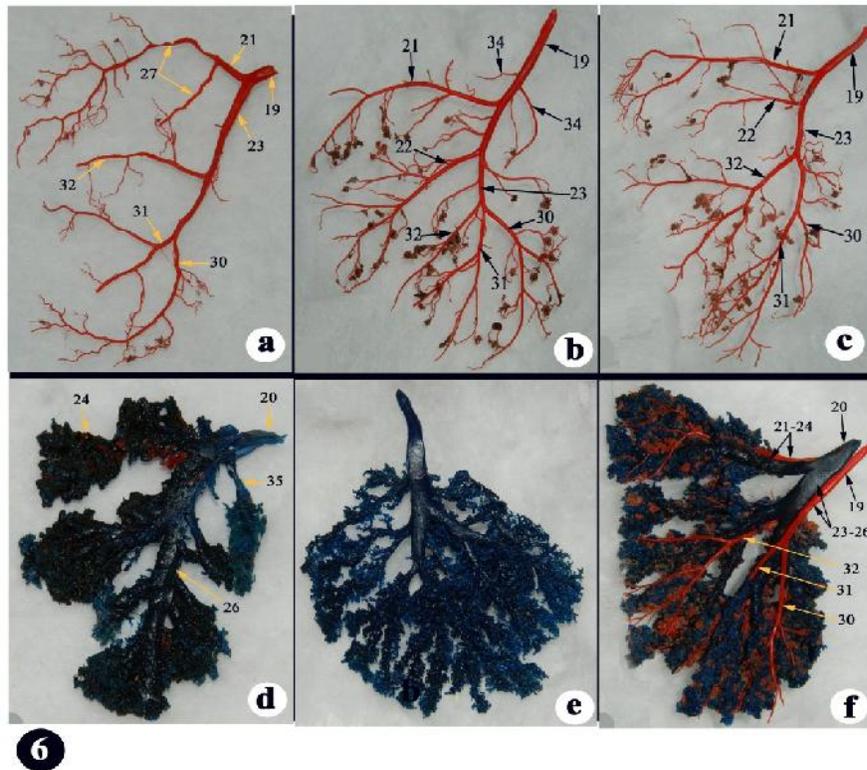


Fig. (6). Corrosion cast photographs of sheep and goat spleens showing the distribution of splenic vasculatures. (a) Splenic artery of sheep. (b),(c) Splenic artery of goat. (d) Splenic vein of sheep. (e) Splenic vein of goat. (f) Splenic artery and vein of goat.

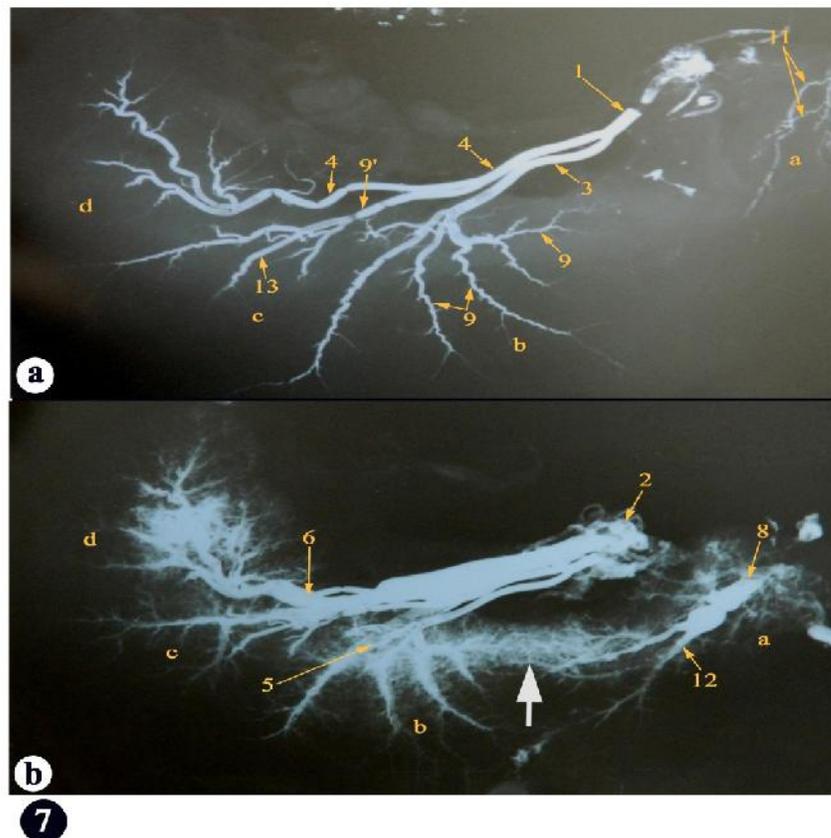


Fig. (7). Radiographic figures of camel spleen showing the distribution of splenic arteries (a), veins (b) and venous anastomosis (white arrow).

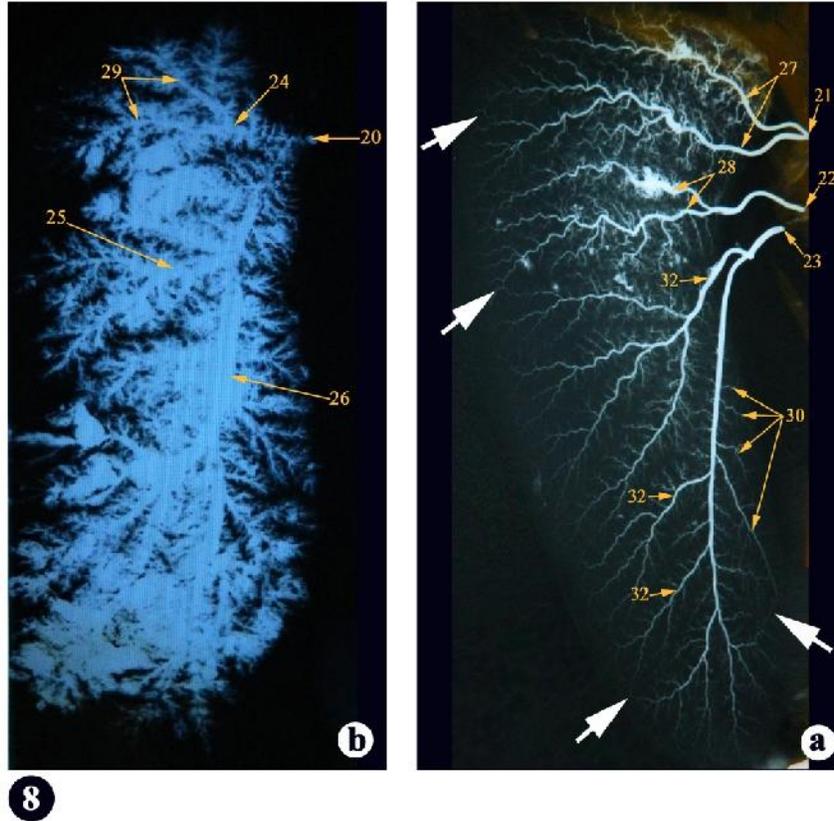


Fig. (8). Radiographic figures of buffalo calf spleen showing the distribution of splenic arteries (a), veins (b) and arterial anastomosis (white arrows).

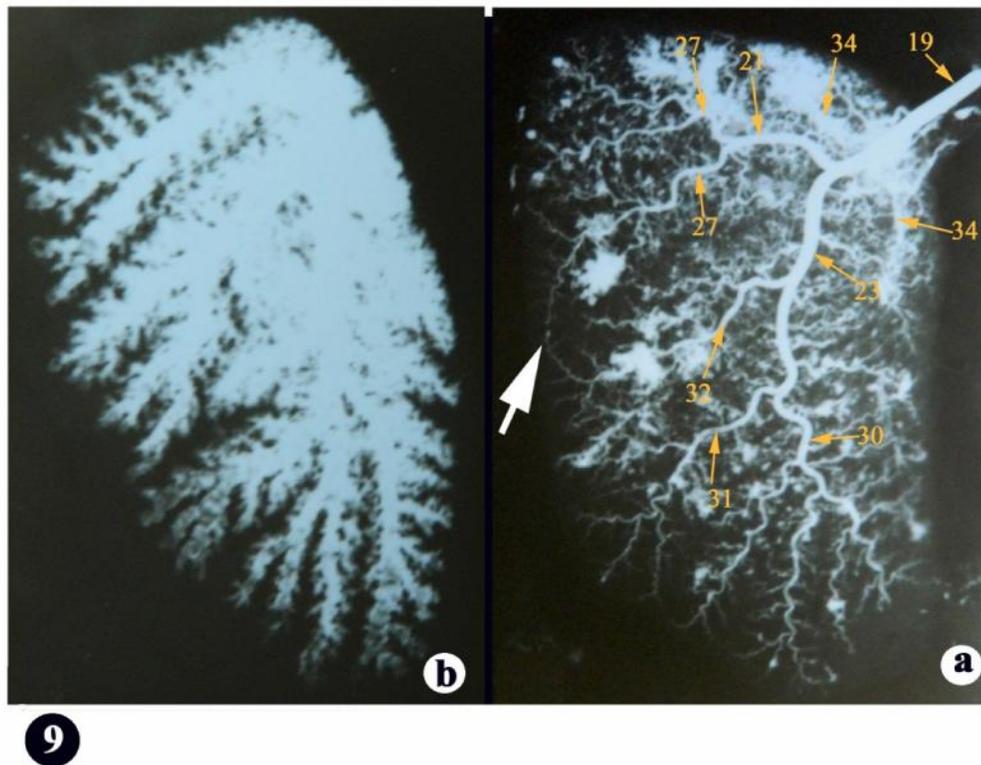


Fig. (9). Radiographic figures of sheep spleen showing the distribution of splenic artery (a), vein (b) and arterial anastomosis (white arrow).

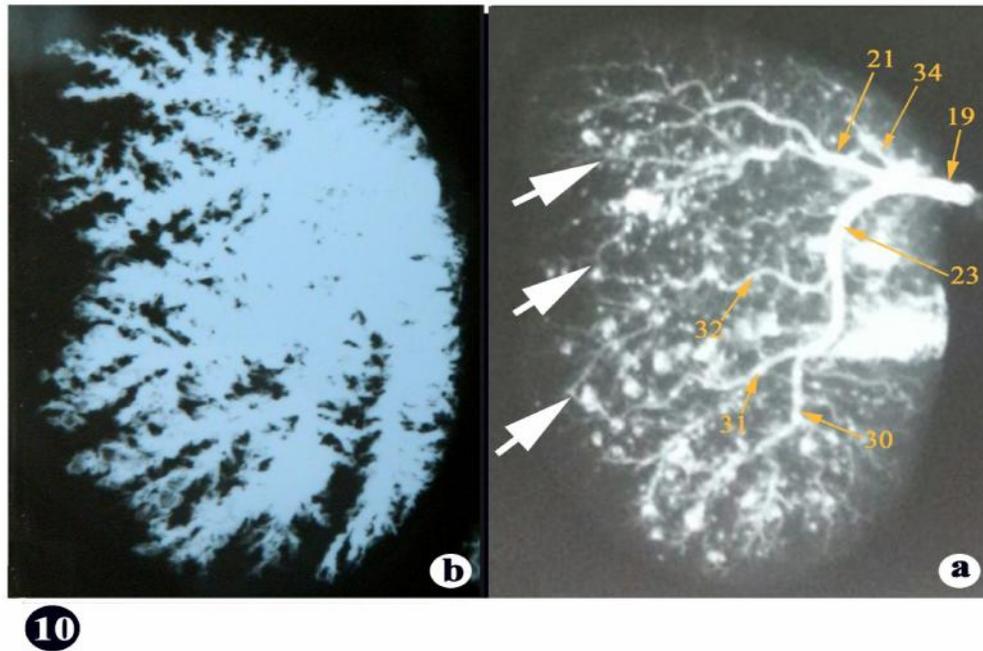


Fig. (10). Radiographic figures of goat spleen showing the distribution of splenic artery (a), vein (b) and arterial anastomosis (white arrows).

Histological Findings: (Light Microscopy, LM)

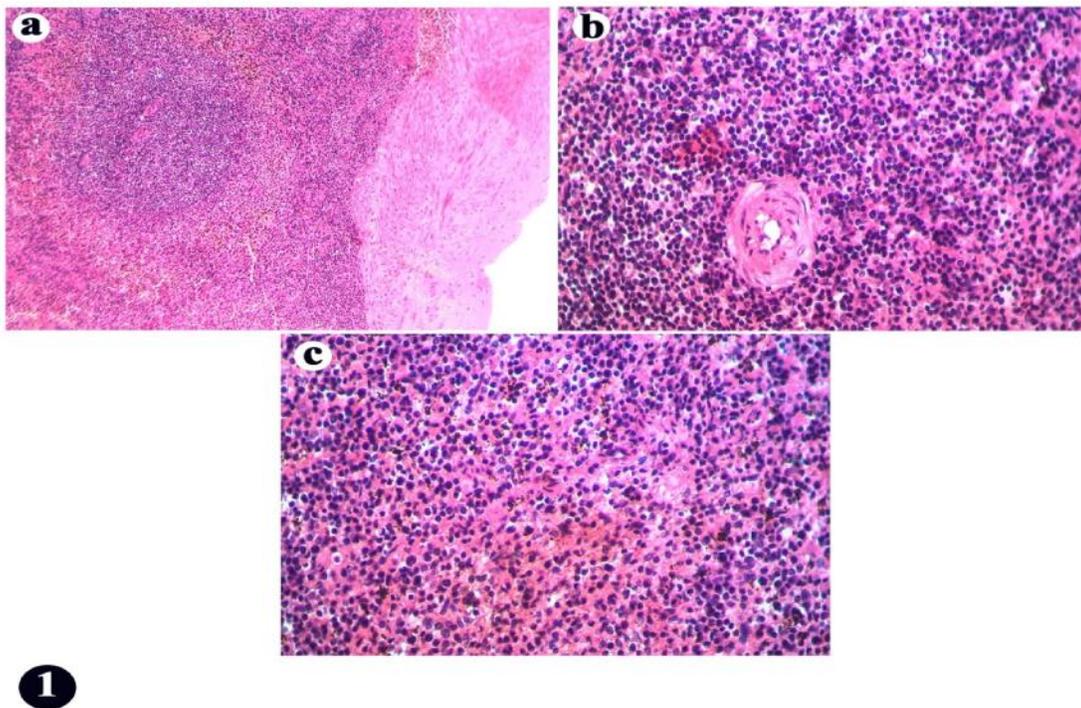


Fig. (1). Light microscopical micrographs of camel spleen, to show:
(fig.a):spleen section of camel with thick fibro muscular connective tissue capsule covered with mesothelium with 3 smooth muscle fibers, layers perpendicular to each other, splenic parenchyma formed of large white pulp formed from activated lymph nodules with prominent nodular artery and lymphoreticular connective tissue and red pulp filling the spaces between white pulp(H&E 100X).
(fig.b):splenic white pulp (lymph nodule) with high density of packed lymphocytes and nodular artery(H&E 400X).
(fig.c):splenic red pulp of showing many pigmented macrophages with minimal sinusoidal spaces were detected(H&E 400X).

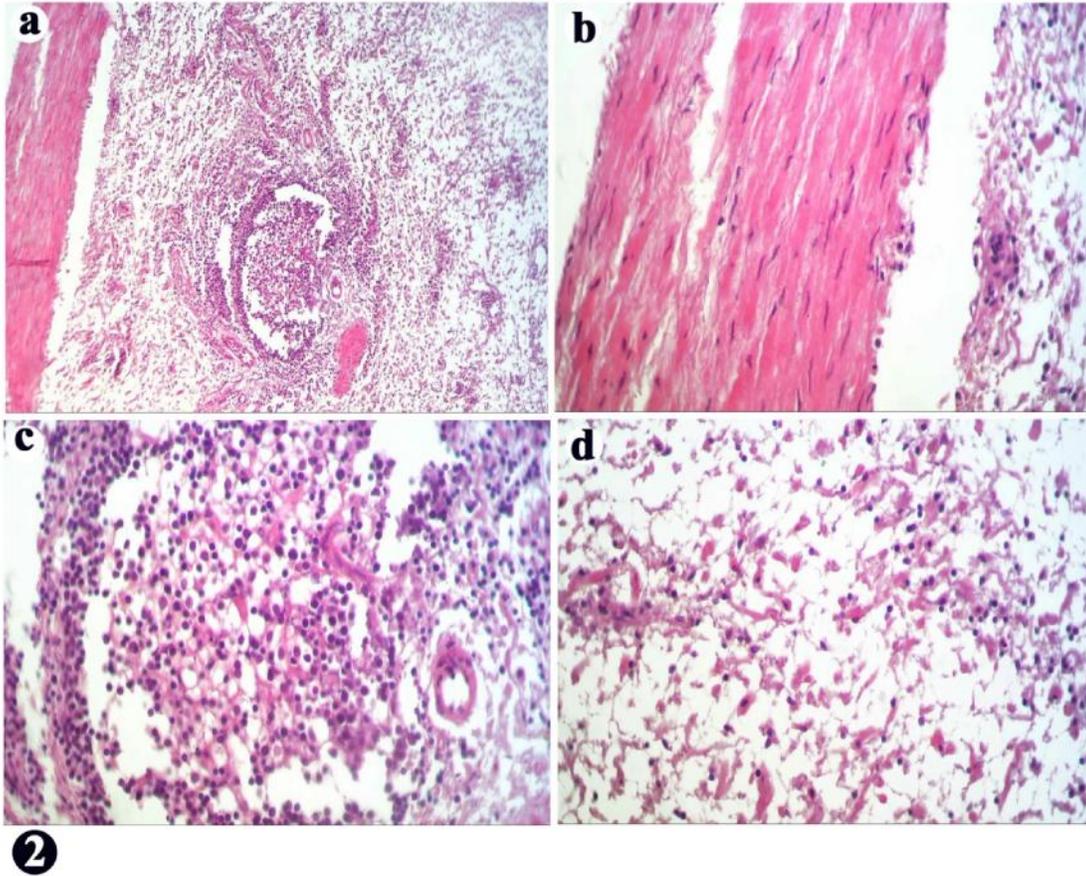


Fig. (2). Light microscopical micrographs of buffalo calf spleen, to show:

(fig.a):spleen section with thick fibromuscular capsule covered with mesothelium, splenic parenchyma formed of white pulp formed from scattered activated lymph nodules with prominent nodular artery and lymphoreticular connective tissue and red pulp filling the spaces between white pulp(H&E 100X).

(fig.b):thick splenic capsule formed of collagen fibers; elastic fibers mixed with smooth muscle fibers with many fibroblasts are observed (H&E 400X).

(fig.c):white pulp (splenic lymph nodule) with prominent nodular artery and housing many lymphocytes. (H&E 400X).

(fig.d):splenic red pulp with splenic cords with scattered RBCs, plasma cells and macrophages. (H&E 400X).

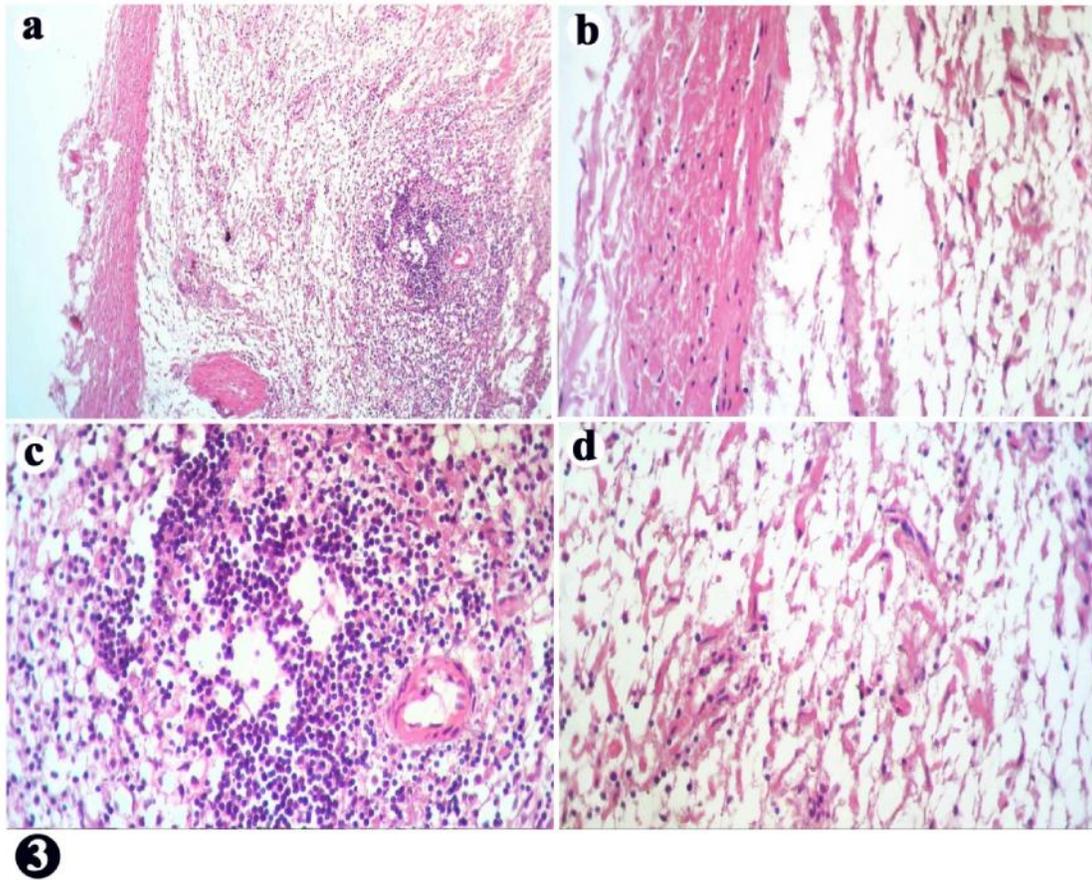


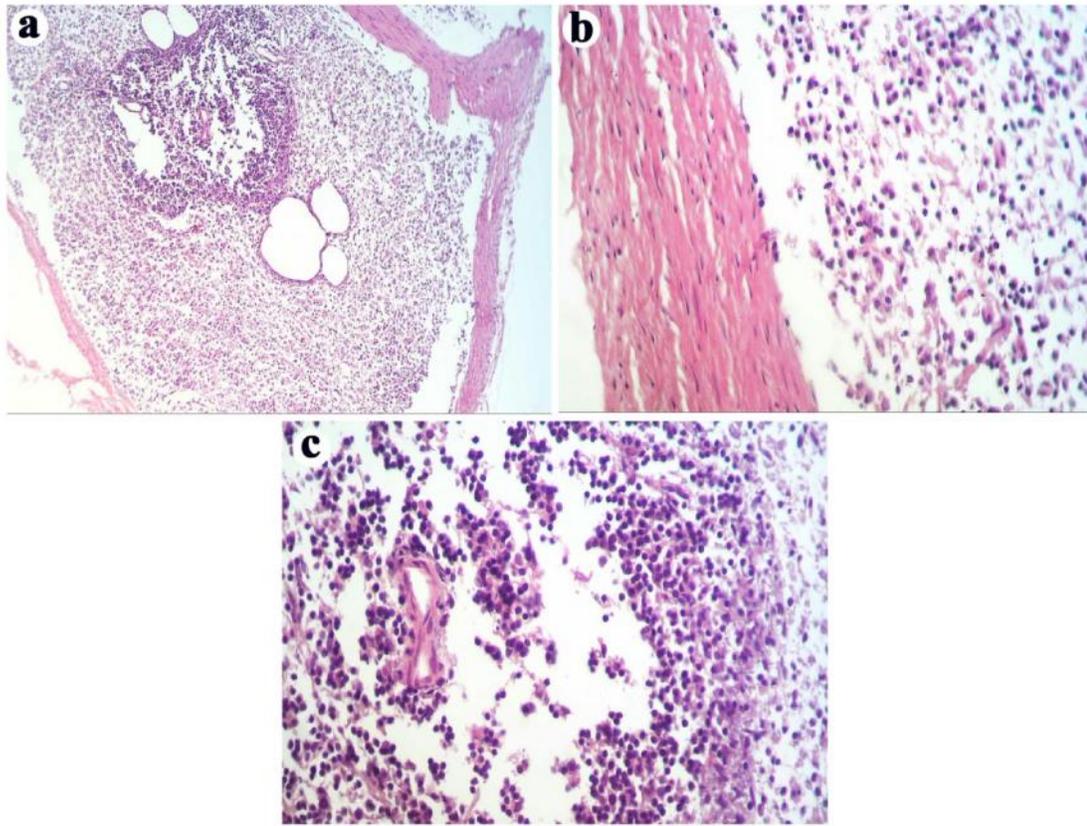
Fig. (3). Light microscopical micrographs of sheep spleen, to show:

(fig.a):spleen section with a thinner fibromuscular capsule covered with mesothelium, splenic parenchyma formed of white pulp formed from scattered lymph nodules with prominent nodular artery and lymphoreticular connective tissue and red pulp filling the spaces between white pulp notice part of trabeculae in bottom part (H&E 100X).

(fig.b):thin splenic capsule have perpendicular layers of smooth muscle fibers with fine collagen and elastic fibers in-between. (H&E 400X).

(fig.c):white pulp (splenic lymph nodule) with prominent nodular artery and housing many lymphocytes (H&E 400X).

(fig.d):red pulp showing scattered smooth muscle fibers with other immunocompetent cells. (H&E 400X).



4

Fig. (4). Light microscopical micrographs of goat spleen, to show:

(fig.a):spleen section with a moderate thick fibromuscular capsule covered with mesothelium, splenic parenchyma formed of white pulp formed from scattered lymph nodules with prominent nodular artery and lymphoreticular connective tissue and red pulp filling the spaces between white pulp notice part of trabiculae in bottom part (H&E 100X).

(fig.b):splenic capsule have layers of smooth muscle fibers run in different directions with fine collagen and elastic fibers in-between. notice the underlying red pulp with many scattered plasma cells, lymphocytes and macrophages (H&E 400X).

(fig.c):white pulp (splenic lymph nodule) with prominent nodular artery and housing many lymphocytes. (H&E 400X).

Histological Findings: (Scanning Electron Microscopy, SEM)

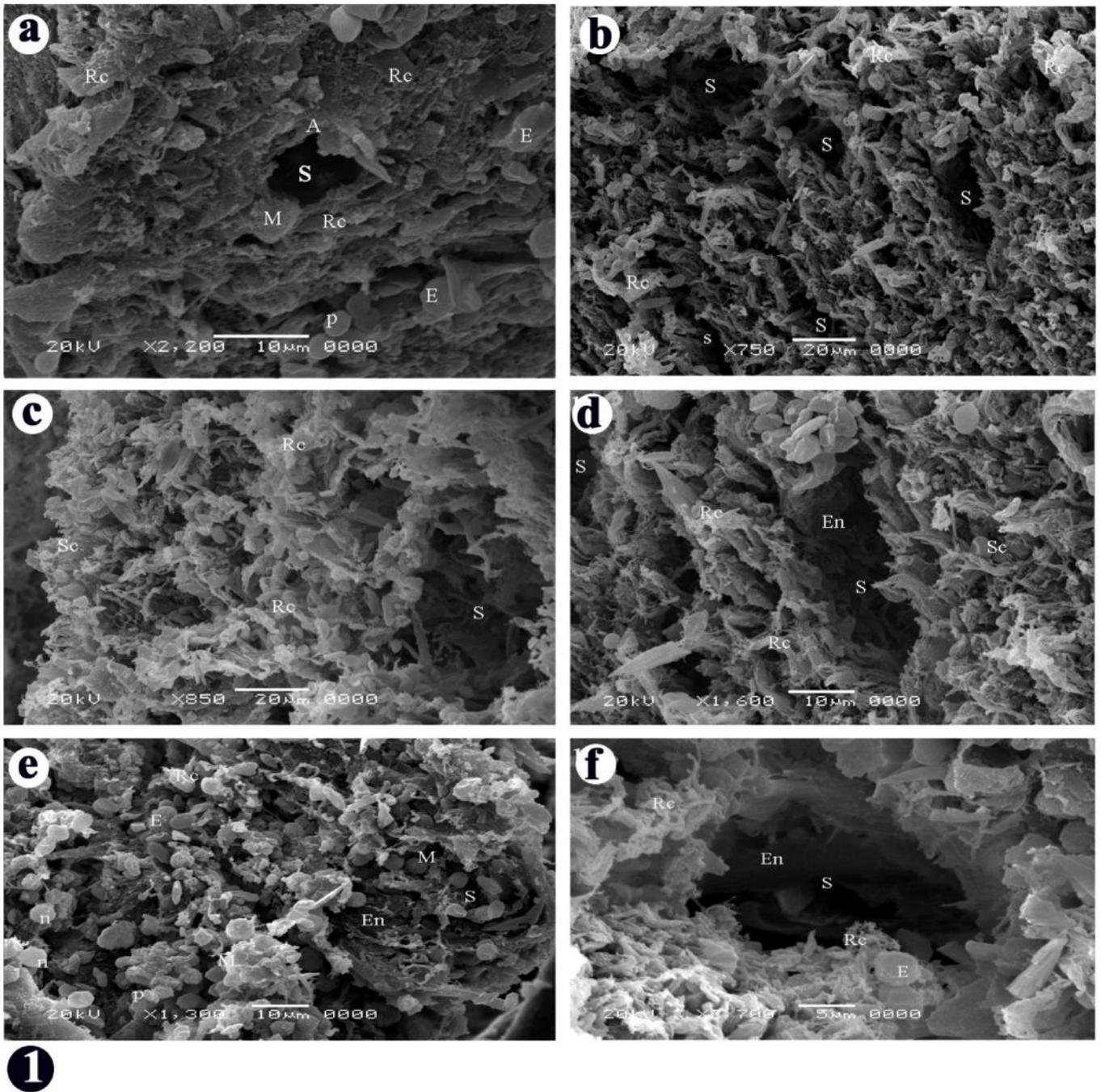
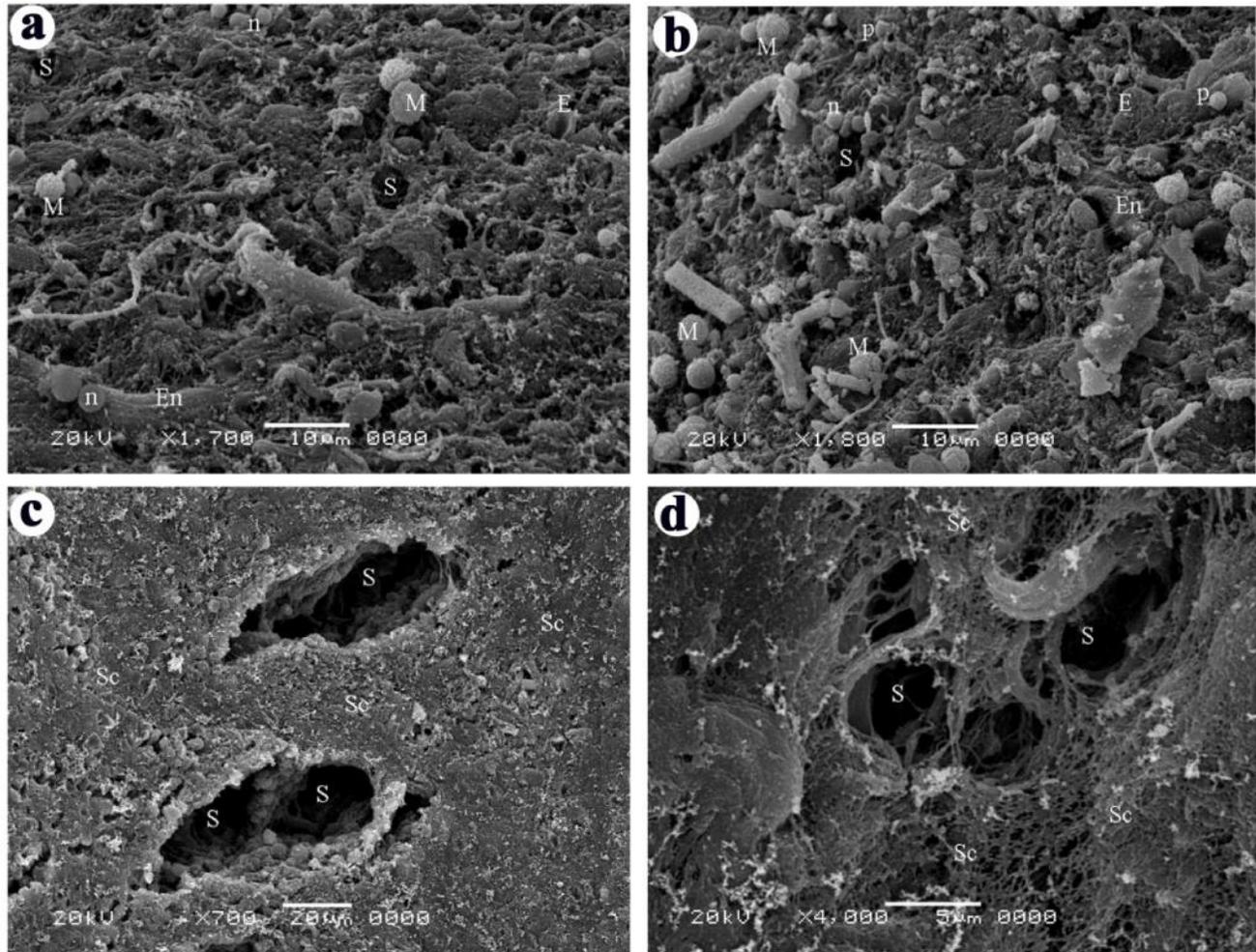


Fig. (1). Scanning electron micrographs of camel spleen, to show:
(fig.a): a sheathed artery (A) and sinus (S) enveloped by macrophages (M) and reticular cells (Rc) as well as sporadic erythrocytes (E) and platelets (p).
(fig.b): the red pulp at low power, showing the sinuses (S) and meshwork formed by reticular cells (Rc), their processes and reticular fibers.
(fig.c,d): the red pulp showing the splenic sinus (S) with rod-shaped endothelial cells (En) and splenic cords (Sc) supported by meshwork of reticular cells (Rc) and reticular fibers.
(fig.e,f): the red pulp showing the inner wall of the vascular sinus (S) with its lining endothelial cells (En) and fenestrations as well as the presence of leucocytes mainly neutrophils (n) and macrophages (M) and crowded by large number of erythrocytes (E), platelets (p), reticular cells (Rc) and reticular fibers and processes.



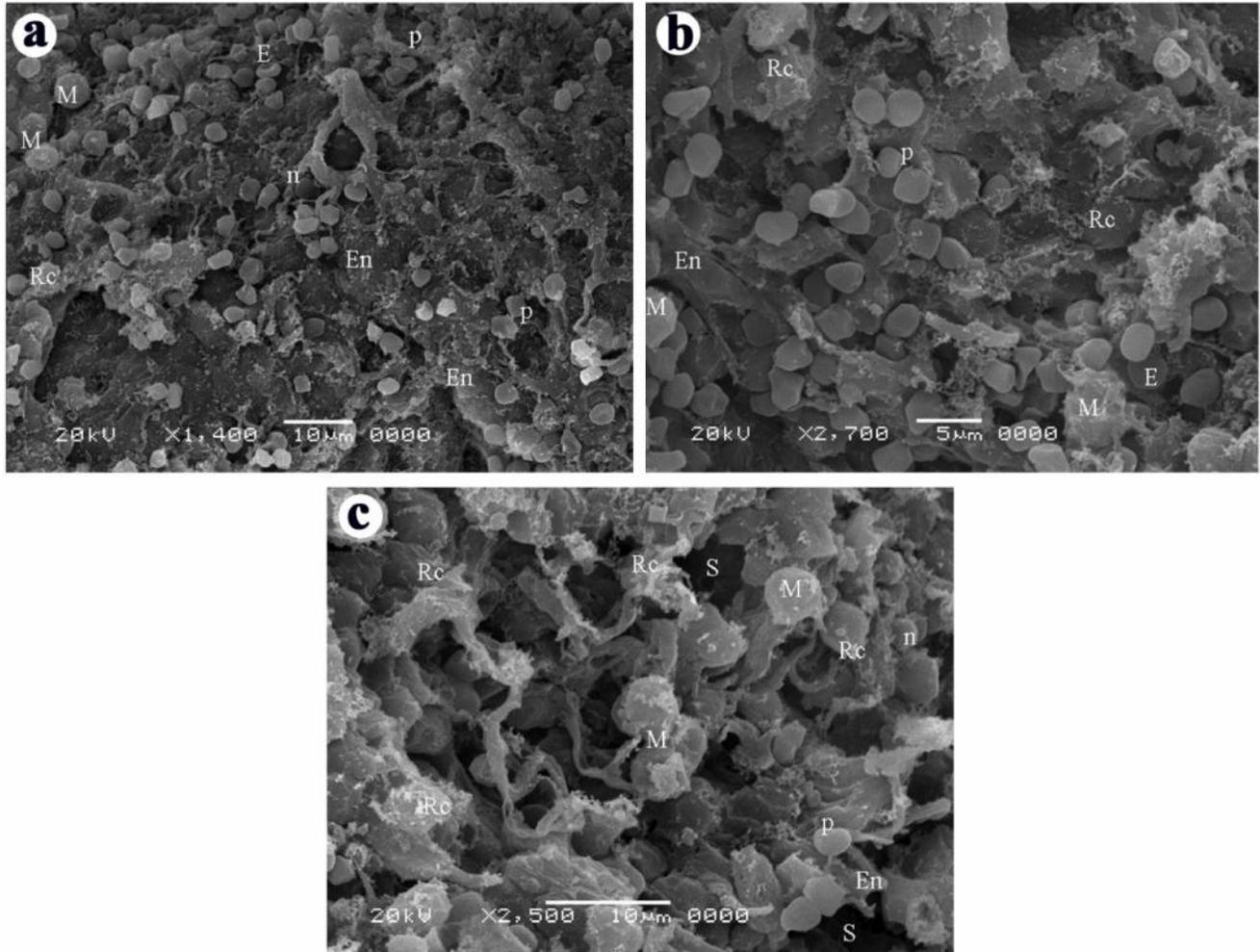
2

Fig. (2). Scanning electron micrographs of buffalo calf spleen, to show:

(fig.a,b): the endothelial cells (En) lie close against one another with few visible gaps. Their smooth surface has many small punctate protuberances. The large free cells laying on the endothelium likely macrophages (M) showing many small projections. The small oval bodies are platelets (p) and few erythrocytes (E).

(fig.c): showing the condensed splenic cords (Sc) and large branching splenic sinuses (S) surrounded and filled with erythrocytes, platelets and reticular cells.

(fig.d): showing the red pulp demonstrating various profiles of the splenic sinuses (S) and the spongy appearance of the splenic cords (Sc). In the wall of the sinuses appear numerous fenestrations and frequent openings of the branching sinuses.

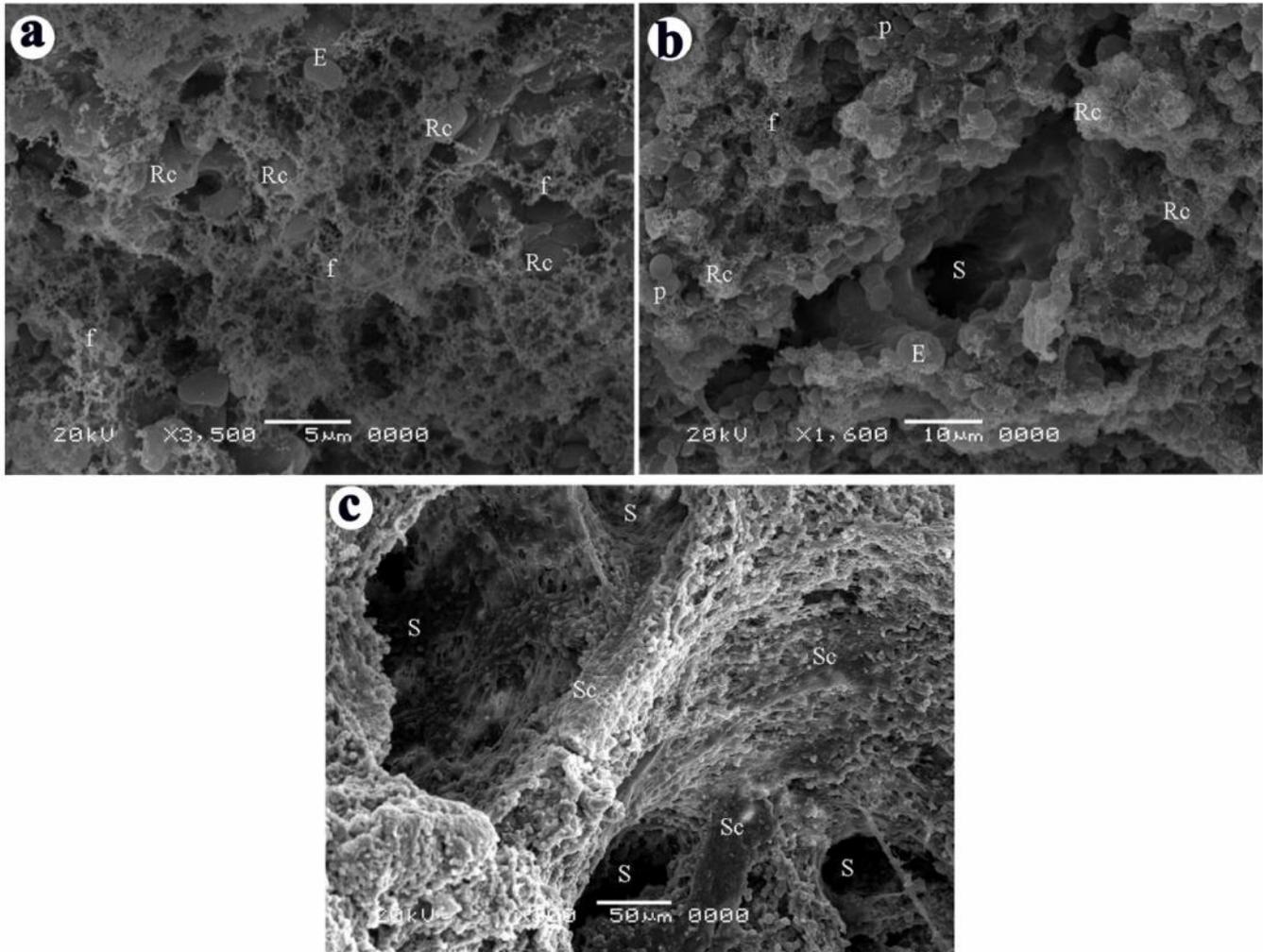


3

Fig. (3). Scanning electron micrographs of sheep spleen, to show:

(fig.a,b): showing the outer surface of sinuses, elevations and protuberances of endothelial cells (En). The surface carrying a wide variety of leucocytes as macrophages (M) and neutrophils (n), erythrocytes (E), platelets (p), reticular cells (Rc) and fibers connected together.

(fig.c): the cross-cutted surface of splenic sinuses (S). The edges of sinuses at the most lower right part represented by the rod-shaped endothelial cells (En) carrying small platelets (p), macrophages (M) with long processes and reticular cells (Rc) with well-developed fibers.



4

Fig. (4). Scanning electron micrographs of goat spleen, to show:

(fig.a): the meshwork formed by reticular cells (Rc) with large amounts of reticular fibers (f) radiating at different directions as well as presence of freezed erythrocytes (E), platelets (p).

(fig.b): the splenic sinuses (S) as well as the meshwork formed by reticular cells (Rc) and fibers (f) in addition to the erythrocytes (E) and platelets (p).

(fig.c): the large branching splenic venous sinuses (S). The inner wall of the sinuses appeared perforated. The sinuses are separated by well-developed splenic cords (Sc) embedded by huge number of erythrocytes, platelets and reticular cells.

Conclusion

Finally, we concluded that the first branch of the splenic artery in camel irrigates the major part of the spleen and its branches penetrate through the caudal margin and directed radially towards the cranial serrated border where the small arterioles terminated without any anastomosis. However, the convex zone

of the spleen of dromedary is the preferred area for splenic biopsy. It avoids the large arteries and consequently avoids the risk of hemorrhage. Good knowledge of the sample biopsy techniques and success of surgical procedures such as splenectomy, resection and splenopathy necessarily pass through good knowledge of the location, number and branches of the arteries as well as the knowledge of the splenic segmentation.

According to the radiographic figures, the arterial anastomosis was very clear in all studied species except the camel while there was a clear venous connection only in the camel between the dorsal splenic segment and the intermediate segment as well as the presence of an additional segment between the intermediate and ventral segments which supplied by a branch from the caudal division of the major splenic artery, a result which characterizes the spleen of camel.

According to the figures of light microscope and scanning electron microscope, all the four species studied were of sinusal type of spleen which was illustrated by the numerous numbers of sinuses and the obvious occupation of the red pulp than the white one and the amount of fibromuscular connective tissue.

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