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TOPOGRAPHY OF INTRARENAL LYMPHATICS

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ABSTRACT

The intrarenal topography of lymph vessels injected with India ink was examined in 32 canine kidneys. In the upper portion of the renal cortex most lymphatics were associated with subcapsular veins and tubules. In the cortical midportion lymphatics were generally aligned with interlobular arteries and veins, glomeruli, and tubules. These lymphatics commonly encircled interlobular arteries and formed an interconnecting plexus adjacent to glomeruli. In the lower portion (i.e., corticomedullary zone), renal lymphatics passed between loops of Henle and collecting tubules.

As early as 1863, Ludwig and Zawarykin (1) described lymphatics in the edematous kidney. More recently, it has been demonstrated that renal lymphatics communicate with hilar lymph vessels and those of the renal capsule (2-5), and within the kidney adjoin intrarenal arteries (6,7). Subsequent studies have focused upon renal lymphatic ultrastructure (4,8-17).

Whereas most investigators acknowledge the presence of lymphatics in the renal cortex, the exact anatomical interrelationships are unclear. Moreover, some investigators propose the existence of lymphatics in the renal medulla both in normal (1,12,19-21) and pathologic states (12,15,21,22). The present study pursues the topography of the intrarenal lymphatic system.

MATERIAL AND METHODS

Thirty-two normal canine kidneys were injected to visualize renal capsular lymphatics immediately after nephrectomy in anesthetized dogs. A cannula (250μm wide) was carefully introduced into lymphatics of the renal capsule at 5-8 sites with the aid of a dissecting microscope. Thereafter, India ink suspension in 2% gelatin heated to 45°C was injected under pressure of 50-100mm H_2O. In some instances the injected solution readily entered capsular lymphatics and filled an area of approximately 0.5-1 sq. cm. The amount of injected material was 0.2-0.5ml. and the duration of injection was 3-10 seconds. In other instances, only a short segment of a lymphatic could be filled. Raising injection pressure to 180-200mm H_2O either further filled lymphatics (on occasion via collaterals) or led to extravasation of India ink. Only those areas devoid of extravasation were used for histologic processing. In eleven kidneys, the India ink injection of lymphatics was combined with either renal intraarterial or intravenous infusion using corpuscular dyes (Seabond-blue, Seabond-orange) suspended in 6% gelatin. Injected kidneys were fixed in 10% formalin for 4 days and thereafter sectioned into 1mm thick slices, dehydrated in alcohol, and cleared in methyl salicylate. Each slice was examined under the dissecting microscope and photographed to demonstrate the macroscopic and microscopic interrelations between lymph vessels and neighboring arteries and veins. Tissue areas with injected lymphatics were subsequently removed for serial histology, dehydrated in alcohol, paraffin-embedded, and sections stained with hematoxylin and eosin, Weigert's iron

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hematoxylin, and Masson's blue trichrome stain. Some sections were cut to follow the course of the cortical interlobular arteries; others were transected perpendicular to these arteries.

RESULTS

Lymphatic drainage of the renal parenchyma is inhomogenous with morphology varying according to number and course of lymphatic channels. In the renal cortex, numerous lymph vessels are seen around interlobular arteries. Lymph channels measuring 10-30 μm in diameter in the superficial areas and 15-50 μm, in the deeper cortical areas form 2-5 irregular strands alongside and interdigitating with interlobular arteries to form plexus-like structures (Fig. 1). This relationship is most apparent around large arteries at the corticomedullary juncture and in the renal hilus around the arcuate artery. Here, lymphatics reach a diameter of 10-70 μm, and those surrounding interlobular arteries are 60-200 μm in diameter. Less prominently lymphatics are seen near adjacent veins (Fig. 2).

In the cortex 2-5mm beneath the capsule, renal arteries terminate and lymph vessels are less intimately attached. Lymphatics, 10-30 μm in diameter, either follow subcortical transverse or longitudinal veins (Fig. 3-5) or pass between tubules independent of veins. Circular rings of lymphatics are visible around transversing veins (Fig. 3), connect with larger channels measuring 150-230 μm in diameter, and either penetrate the capsule alone or accompany perforating veins and arteries. A small number of lymphatics are detectable near tubules between interlobular arteries. Here, lymph vessels, 4-15 μm in diameter, appear as oblique or transverse channels (complete or incomplete) with branches interconnecting with other lymphatics adjacent to interlobular arteries (Fig. 1). These thin, connecting longitudinal branches are only 4-7 μm in diameter and pass alongside the tubules (Fig. 5). Lymphatics surrounding the glomerulus measure 4-10 μm in

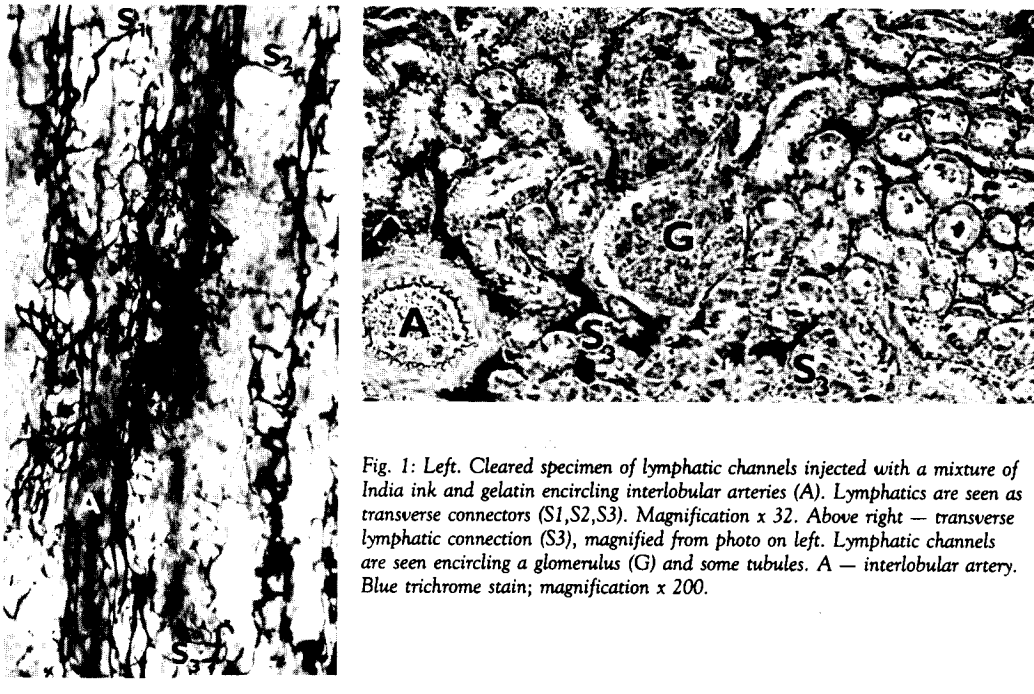

Fig. 1: Left. Cleared specimen of lymphatic channels injected with a mixture of India ink and gelatin encircling interlobular arteries (A). Lymphatics are seen as transverse connectors (S1,S2,S3). Magnification x 32. Above right — transverse lymphatic connection (S3), magnified from photo on left. Lymphatic channels are seen encircling a glomerulus (G) and some tubules. A — interlobular artery. Blue trichrome stain; magnification x 200.

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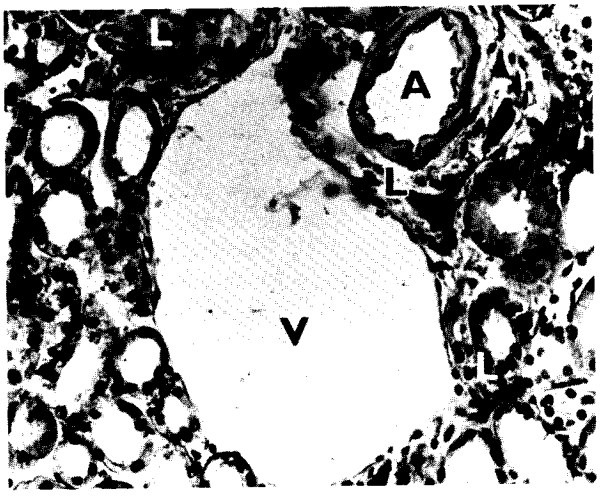

Fig. 2: India ink injected lymphatics (L) encircling interlobular artery (A) and vein (V) in the distal cortex. A few lymphatics are detectable abutting the vein wall remote from the artery. Hematoxylin and eosin; magnification x 400.

Fig. 3: Lymphatics (L) encircling a vein (V) in the uppermost portion of the cortex. Compare the photomicrograph with the cleared specimen (inset). Hematoxylin and eosin; magnification x 200.

diameter and form a loose network with one or two loops (Fig. 1). Lymph channels adjacent to glomeruli abut on these transverse and oblique communications (Fig. 1). The number of lymphatics surrounding the glomeruli decreases as the distance between glomeruli and interlobular arteries increases. Sometimes lymphatics are tangentially contiguous with the glomeruli. In accordance with previous investigators, we were unable to detect lymphatics in the renal medulla. On the other hand, lymphatics can be seen encircling loops of Henle and collecting tubules in the corticomedullary zone (Fig. 6). No intrarenal lymphatic-venous shunts were detected although high pressure injection ($\sim$180mmH_2O) occasionally forced India ink into adjacent capsular and subcapsular veins. These findings are summarized in a schematic diagram (Fig. 7).

DISCUSSION

These observations in conjunction with those of Bell et al (23) indicate the feasibility of retrograde injection of renal lymphatics via capsular channels despite presence of intraluminal valves. Although injection of lymphatics was considered satisfactory when filling extended into the finer radicles, this was not always possible. In cleared preparations and histologic sections, extravasated India ink appeared as black bands concentrically enveloping renal tubules, and readily distinguishable from a lymphatic plexus. These preparations were specifically excluded from study. Injections of blood vessels with corpuscular pigments in conjunction with intralymphatic infusion with India ink, facilitated delineation of the pattern and pathways of the intrarenal lymphatic system.

Demonstration of cortical interlobular lymphatics and lymph channels penetrating the renal capsule confirmed earlier findings (9,13,15,24,25). Moreover, we were unable to detect renal lymphatics in the medulla proper (12,18-20,26). On the other hand, lymphatics were visualized within medullary rays adjacent to collecting tubules and loops of Henle close to the cortical glomeruli. These findings conformed to those of Albertine and O'Morchoe (27) who demonstrated lymphatics adjacent to medullary vasa recta.

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Fig. 4: Left — longitudinal vein (V) in the upper portion of the cortex with encircling lymph vessels (L). Cleared specimen; magnification x 55. Right – photomicrograph of the squared area on left. Lymphatics (L) are seen passing alongside veins (V) as well as between tubules. Hematoxylin and eosin; magnification x 300.

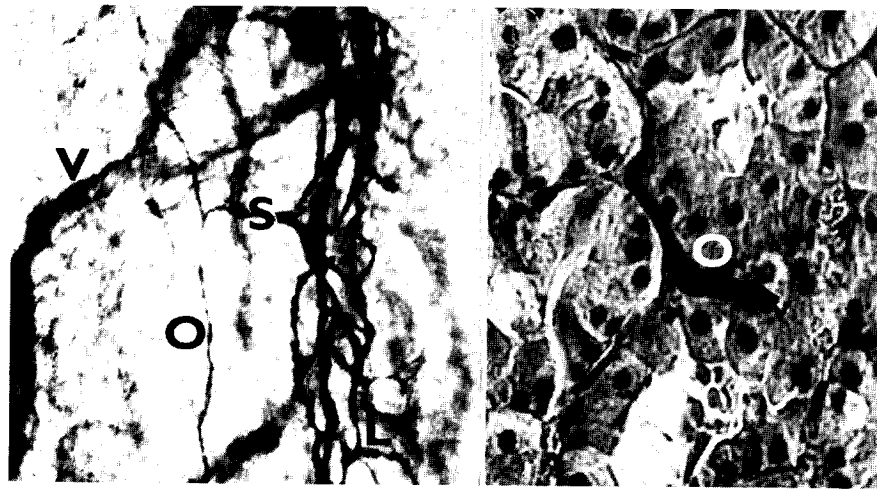

Fig. 5: Left – lymphatics (L) forming a network along an interlobular artery, in the mid-portion of the cortex. A transverse branch (S) is seen dividing into an ascending and descending channel (O). V = cortical vein. Cleared specimen. Magnification x 50. Right — photomicrograph corresponding to the area depicted on the left demonstrating that the lymphatic channel (O) is located between tubules. Hematoxylin and eosin; magnification x 400.

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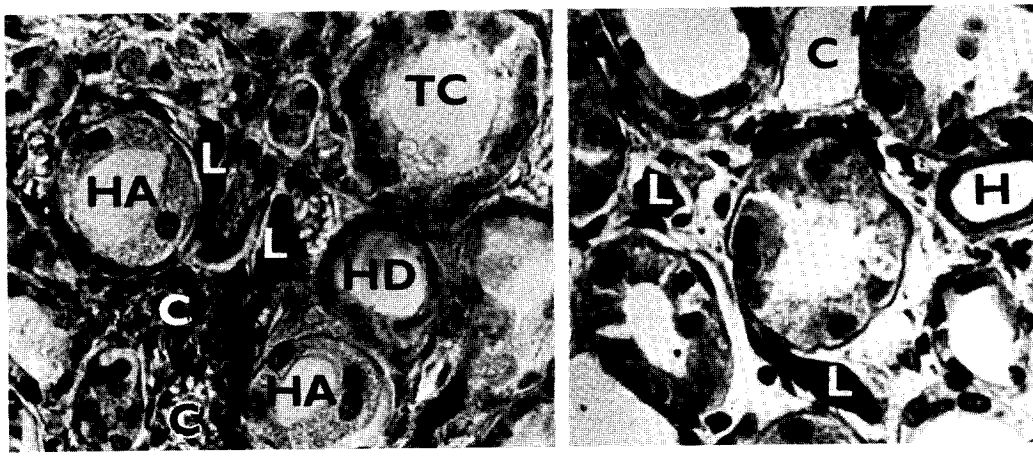

Fig. 6: Left — lymphatics (L) located betweeen the tubules of Henle's loop, specifically the ascending (thick) segment (HA) and descending (thin) segment (HD). A collecting tubule (TC) and a capillary (C) are also seen. Weigert's iron hematoxylin; magnification x 750. Right — lymphatics (L) in the medullary rays between collecting tubules, capillaries (C) and a nearby loop of Henle (H). Hematoxylin and eosin; magnification x 750.

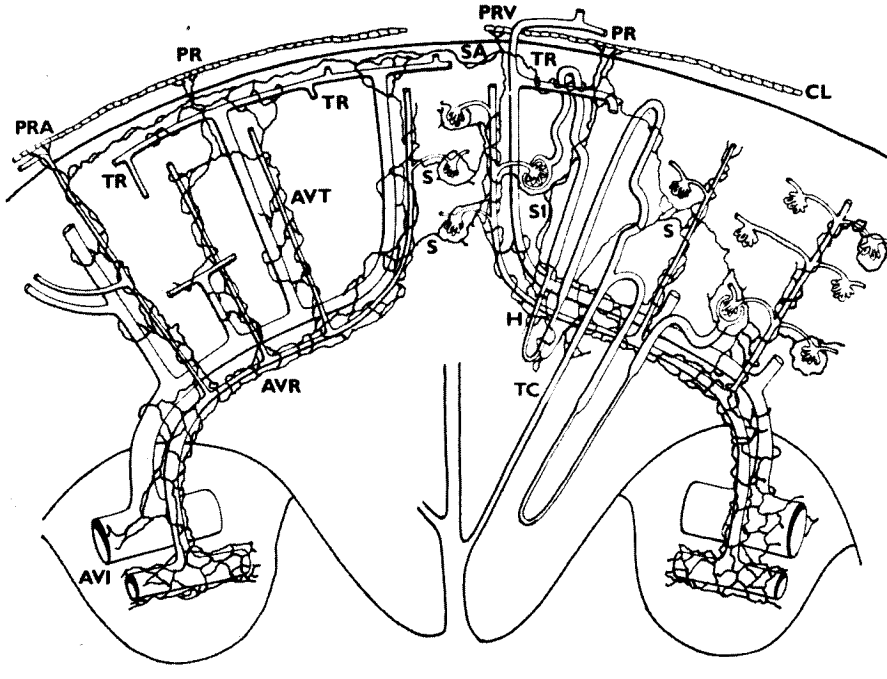

Fig. 7: Schematic diagram of canine intrarenal lymphatics. Starting on the lower left the course of lymphatics accompanying blood vessels is depicted while on the right lymphatic pathways are shown accompanying renal tubules. AVI — lymphatics accompanying interlobular artery and vein, AVR — lymphatics accompanying arcuate artery and vein, AVT — lymphatics accompanying interlobular artery and vein, TR — lymphatics accompanying the longitudinal and transverse subcortical veins, PR — lymphatics alone penetrating the renal capsule, PRA — lymphatics along with artery penetrating the capsule, PRV — lymphatics with vein penetrating the capsule. SA — subcapsular lymphatic connections, CL — capsular lymphatics, S — lymphatic plexus near glomeruli, S1 — transverse lymphatic dividing into ascending and descending branches alongside tubules, H — lymphatics accompanying loop of Henle, TC — collecting tubules.

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The origin of renal lymph remains controversial with hypothetical sources including Bowman's capsule, tubules, and pericapillary interstitial filtrate (15). Based on topographic delineation of intrarenal lymphatics it is reasonable to propose that in the uppermost part of the cortex, renal lymph derives from pericapillary filtrate (28-30) whereas in the mid-portion lymph possibly originates also form tubular reabsorbate (9,15,31-34). In the lower portion or corticomedullary area where lymphatics encircle collecting tubules in the loop of Henle adjacent to arcuate interlobular arteries and veins, lymph probably represents interstitial fluid drained from the innermost portion of the medulla (35) and may thereby reflect medullary tissue osmolality. Failure to demonstrate intrarenal lymphatic-venous shunts conforms to the findings of Hogg et al (36) suggesting that once intrarenal lymph collects, only extrarenal pathways carry it back to the venous system.

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