INTRODUCTION

The health of the oviduct circulation is very important for normal egg formation. Vascularization of the oviduct is of primary value in the egg quality, and continuity of the production and vascular impairment may play a role in pathological production of egg and offspring. In addition, lymphatics play a role in immunity and in regulating interstitial fluid.

The left oviduct of quail is well developed, and the right one is atrophied (El-Desoky, 2015). In addition, birds’ oviduct consists of the following segments infundibulum, magnum, isthmus, uterus and vagina (Ibrahim, Ahmed, Mokhtar, & El-Desoky, 2015; Khokhlov & Kuznetcov, 2007; Reed, Cope, & Blackford, 2011).

Different parts of the oviduct were subjected to various changes during egg formation beginning from transportation of the ovum from the ovary with the infundibulum of the oviduct, accumulation of egg white proteins in the magnum, shell membranes formation in the isthmus, the hard shell synthesis in the uterus and sperm in the vagina (Jung et al., 2011).

Cranial, middle and caudal oviductal arteria gave the blood supply to the oviduct of birds (Getty, 1975; Hodges, 1965; Mohammed, 2010; Munaff & Baraj, 2015). Quail was characterized by short life cycle, low breeding cost and easy to raise so it is ideal for research purposes and an excellent source of egg and animal protein (Mohamed, Selim, Abdelhafeez, & Mohamed, 2017; Vali, 2008).

Histological description of the vessels of the oviduct of quail may guide to improve their egg quality and quantity and relieve problems which link with the blood vessels. The previous studies have been done and describe the characteristic histomorphological character of the oviduct in many avian species but there is no research before describing the histological structure of the vessels of the different segments of the oviduct; the aim of the present work was to give detailed information on the different types of vessels of the oviduct of quail.

MATERIAL AND METHODS

2.1 Sample collection

Samples of the current study were collected from the Faculty of Agriculture and Faculty of Science quail farms of Assiut University and South Valley University, respectively. The samples included in this work were obtained from the female genitalia of five healthy Japanese quail (Coturnix japonica) at 4 months of age. The birds were
anesthetized with xylazine–ketamine combinations at the dose rate of 2 mg xylazine and 10 mg ketamine per kg that injected to breast muscle.

2.2 | Histological examination

Specimens were dissected as soon as possible from infundibulum, magnum, isthmus, uterus and vagina of the oviduct. All specimens were immediately fixed in Bouin’s solution. The fixed specimens were dehydrated, cleared, embedded in paraffin wax, sectioned at a thickness of 4 μm and stained with Harris’s haematoxylin and eosin, Crossmon’s Trichrome and Wigert’s Elastica. Histochemical analysis was performed using periodic acid–Schiff (PAS) technique for demonstration of neutral mucopolysaccharides and alcian blue technique (pH 2.5) for the demonstration of acid mucopolysaccharides (Bancroft & Gamble, 2002).

For semithin sections, other small specimens from the infundibulum, magnum and uterus of the oviduct were used for semithin sections. Small pieces 2.0–3.0 mm long from uterus were placed on 2.5% cold glutaraldehyde in phosphate buffer (pH 7.2) for 24 hr. The samples were washed two times in 0.1 M phosphate buffer and post-fixed in 1% osmium tetraoxide, in the same buffer. The post-fixed samples were dehydrated in alcohols then embedded in araldite resin. Semithin sections (1 μm) in thickness will be stained with 1% toluidine blue (Karnovsky, 1965).

Expressions in this paper are in compatible to Nomia Anatomia Veterineria (2012).

3 | RESULTS

3.1 | Infundibulum

In the mesentery of the infundibulum of the oviduct, arteria was congested and its wall formed of a thin layer of flat endothelial cells and muscular media consisted of 3–5 layers of smooth muscle fibres and thin fibrous adventitia (Figure 1a). In addition, venae were congested wide thin-walled vessels and lymphatics appeared as thin-walled wide-lumened vessels. Moreover, valves were observed in some of lymphatics (Figure 1a).

Stratum vascularies were observed at the middle of the muscular layer of the infundibulum and formed of different types of vessels of different sizes. Arteria was characterized by tunica media of circularly arranged smooth muscle fibres (2–3 layers) and thin adventitia rich in collagenous fibres. In addition, the PAS-positive reaction was demonstrated in the inner part of the arterial wall. However, venae showed a wide irregular lumen and thin wall. PAS-positive reaction was demonstrated in the venae wall (Figure 1b,c). Furthermore, lymphatics were characterized by their wide lumen and thin fibrous wall. Some of these vessels demonstrated valves (Figure 1d). Arteriolae and venulae can also be observed within the stratum vascularies. Arteriolae wall consisted of 1–2 smooth muscle fibre-thick media surrounding a thin tunica intima and encircling by thin fibrous tunica adventitia. However, venulae appeared irregular with a very thin wall consisted of endothelium surrounded by thin connective tissue layer (Figure 2a).

![Figure 1](https://example.com/figure1.png)

**Figure 1** Vessels of the infundibulum of the oviduct in mesentery region (a) and in stratum vascularies (b–c and d). (a) Arteria (A), venae (V), lymphatic vessels (L), tunica media (black arrowhead), endothelium (black arrow) and tunica adventitia (white arrowhead) (Harris haematoxylin and eosin). (b) Arteria (A), venae (V), tunica media (black arrowhead) and tunica adventitia (white arrowhead) (Crossmon’s Trichrome). (c) Artery (A), vein (V), PAS-positive reaction observed in the arterial wall (black arrowhead) and venae wall (black arrow) (PAS). (d) Lymph vessel (L) showed valve (black arrow) (Harris haematoxylin and eosin)
Several congested arteriolae and venulae were observed within the lamina propria of the infundibulum of the oviduct. In addition, a dense capillary network can also be demonstrated especially in sub-epithelial position (Figure 2b,c).

### 3.2 | Magnum

Mesenteric arteria of the magnum of the oviduct exhibited a large diameter and thick wall. Membrana elastica interna of arteria appeared well developed beneath the endothelium, and the muscular layer consisted of 5–7 layers of circularly arranged smooth muscle fibres. Clear fibrous adventitia was observed rich in collagenous fibres (Figure 3a). Venae were observed as wide vessels of different size. The tunica intima was surrounded by a thin tunica media encircled by a thick adventitia which is rich in collagen fibres (Figure 3b). In addition, thin wall lymphatics may contain valves and dark brown pigment distributed within the wall (Figure 3c,d).

Several arteriolae were demonstrated within the magnum mesentery. These blood vessels were composed of 1–3 smooth muscle fibre-thick tunica media encircling a thin tunica intima.
with unclear membrana elastica interna and surrounded by tunica adventitia which composed mainly of collagen fibres. Dark brown pigmentation was observed within the arterioles wall. On the other hand, venulae appeared as thin wall vessels engorged with blood and its wall showed dark brown pigmentation (Figure 4a). Moreover, venae of special structures observed within the magnum mesentery and characterized by a wide irregular lumen and thick adventitita mainly consisted of collagenous fibres which contained batches of longitudinally arranged smooth muscle fibres (Figure 4b).

Stratum vascularies located at the middle of the inner circular smooth muscle of the tunica muscularies of the magnum of the oviduct and contained arteria, venae, lymphatics and special types of blood vessels. Arteria and venae were congested and appeared larger in diameter with a thicker wall than those of the stratum vascularies of the infundibulum. Lymphatics were composed of tunica intima surrounded by a fibrous layer mainly of collagenous fibres and the valves mainly thin and composed of a single cellular layer. The wall and valves of lymph vessels showed a PAS-positive reaction (Figure 5a–c). Arterioles and venulae appeared congested and with a thicker wall than those of the stratum vascularies of the infundibulum (Figure 5d).

Various special structure vessels were demonstrated within the stratum vascularies of the magnum. Some special structures arteria showed very thick tunica media formed of thick inner circular smooth muscle fibres and an outer layer of smooth muscle fibres arranged longitudinally. In some arteria, the outer smooth muscle layer run longitudinally or obliquely and condensed at one side of the vessel. Some arteria showed clear inner circular smooth muscle fibres surrounded by few smooth muscle fibres arranged longitudinally at one side of the vessel wall (Figure 6a–c). Other arteria showed irregular lumen and smooth muscle arranged at different directions with different thickness 1–3 layer-thick media (Figure 6d). Venae of special structures characterized by a wide lumen and the endothelial cells were surrounded by inner circular smooth muscle fibres and
Figure 6: Special structures vessels demonstrated within the stratum vasculaires of the magnum. (a-b and c) Arteria of special structures (A), circular smooth muscle fibres (black arrows), longitudinal smooth muscle fibres (black arrowheads) and oblique smooth muscle fibres (white arrowhead) (figure a and b stained with Harris haematoxylin and eosin and figure c stained with Crossmon’s Trichrome). (d) Artery of special structure (A), vein of special structure (V), smooth muscle arranged at different directions (black arrowheads), circular smooth muscle fibres (black arrow) and longitudinal smooth muscle fibres (white arrowhead) (Harris haematoxylin and eosin). (e) Artery (A), vein (V), arterioles of a special structure (black asterisk), endothelium (black arrowhead) and glomus cells (black arrow) (Crossmon’s Trichrome).

Many ordinary structure vessels were observed within the lamina propria of the magnum of the oviduct. In addition, special types of blood vessels were also demonstrated. Arteria of the special structure showed an intimal cushion-like thickening.

Figure 7: Vessels observed within the lamina propria of the magnum of the oviduct. (a) Arteriola (arrowhead), venula (black asterisk) and lymphatic vessels (L) (Crossmon’s Trichrome). (b) Semithin section of the artery of special structure (A) showed an intimal cushion-like thickening consisted of glomus cells (white arrowhead) and fine elastic fibres (black arrow) and glomus cells (black arrowheads). (c) Spirally oriented venula (black asterisk) showed numerous narrowing points along its spiral coarse fibres (black arrows) (Harris haematoxylin and eosin).
consisted of glomus cells and fine elastic fibres and tunica media rich in glomus cells. In addition, spirally oriented venula was characterized by numerous narrowing points along its spiral course (Figure 7a–c).

### 3.3 Isthmus

Stratum vascularies of the isthmus of the oviduct located at the middle of the inner circular smooth muscle of the tunica muscularies and contained many arteria, venae and lymphatics. Arteria exhibited clear membrana elastica interna and a large number of elastic fibres at the adventitia (Figure 8a,b). In addition, arteria of special structures was observed in the stratum vascularies of the isthmus and demonstrated double tunica media formed of thick inner circular smooth muscle fibres and a thin outer layer of smooth muscle fibres arranged longitudinally (Figure 8c).

Histological examination of the lamina propria of the isthmus of the oviduct revealed many ordinary structure vessels. However, some arteriole possessed a very narrow lumen (Figure 8d).

### 3.4 Uterus

Different types of vessels were observed at mesentery of the uterus of the oviduct. Arteria of different size was observed with 3–7 layer-thick tunica media surrounded by thin fibrous adventitia which is rich in collagenous fibres (Figure 9a). Venae were characterized by the wide irregular engorged lumen. The tunica intima was surrounded by a thin media forming of 1–2 layer of smooth muscle fibres surrounded by a relatively thicker fibrous adventitia (Figure 9b). Furthermore, the adventitia of some venae showed scattered pigmentation patches (Figure 9c). Lymphatic vessels were composed of an intimal tunic encircled by a thin fibrous layer mainly of collagenous fibres with dark brown pigment patches of different sizes (Figure 9a,d). Several arteriole were also demonstrated within the mesentery and characterized by tunica media 1–2 smooth muscle fibre thick, encircling a thin intima and surrounded by thin tunica adventitia, sometimes contained dark brown pigmentation (Figure 9e). Venulae wall was thin and consisted of an intimal tunic surrounded by single layer-thick tunica media of smooth muscle fibres coated by fibrous adventitial tunic which contained different sizes patches of dark brown pigment (Figure 9f).

Various blood vessels of a special structure were detected within the mesentery of the uterus of the oviduct exhibited narrow lumen and irregular coarse with a hyperplastic media and thin adventitia (Figure 10a,b). In addition, some venae represented irregular wide lumen, dark brown pigment and smooth muscle fibres observed at various directions (Figure 10c). Spirally oriented arteriole were present within the mesentery of the uterus with a narrow lumen and thick muscular media (Figure 10d).

Stratum vascularies located between the inner circular and outer longitudinal smooth muscle of the tunica muscularies of the uterus of the oviduct and contained different types of arteria, venae, lymphatics and blood vessels of special structure (Figure 11a). In addition,
the stratum vascularies of the uterus of the oviduct showed a series of regressive changes. The arteria demonstrated intimal sclerotic changes. These changes included extreme thickening of the wall with an increase in collagenous fibrous content of the wall and accompanied by narrowing of the lumen of arteria (Figure 11b). These sclerotic changes of the vessel wall gave positive reactions for neutral mucopolysaccharides (Figure 11c). Atypical glomus vessels were recorded within the stratum vascularies. The wall of these vessels was relatively thick and contained a few glomus cells (Figure 11d). In addition, several atypical glomus vessels showed spirally oriented coarse, narrow lumen and extreme thickening of their walls. The latest type of atypical glomus media was formed of inner circular smooth muscle surrounded by several layers of glomus cells (Figure 11e,f).

Several arteriole of a special structure were observed in the stratum vascularies of the uterus of the oviduct and characterized by narrow lumen and glomus cells media (Figure 12a). Another arteriole was spirally oriented with a thick wall and narrow lumen (Figure 12b). In addition, dark brown pigment was observed near some arteriole and venule (Figure 12c).

Lamina propria of the uterus of the oviduct revealed various ordinary structure vessels. In contrast, some arteriole showed an intimal cushion-like thickening of longitudinal smooth muscle cells surrounded by fine elastic fibres which is encircled by tunica media that rich in glomus cells (Figure 12d).

### 3.5 | Vagina

Stratum vascularies of the vagina of the oviduct located between the inner circular and outer longitudinal smooth muscle of the tunica muscularies and contained many vessels of ordinary structure and special types of blood vessels. Glomus vessels of a typical structure with a narrow lumen and glomus cells media were observed with the close association of its afferent and efferent vessels (Figure 13a). In addition, dark brown pigmentation was closely related to some vessel wall (Figure 13b). Our observation revealed that there were arteria of a special structure with a narrow lumen and surrounded by tunica media of circularly oriented smooth muscle fibres (4–7 layer) and patches of longitudinally smooth muscle fibres in between them (Figure 13c).

Some arteria of the stratum vascularies of the vagina exhibited a series of regressive changes. These changes included intimal sclerotic metamorphoses that may be continued to involve the whole wall. These changes lead to an increase in the wall thickening with an increase in collagenous fibrous content of the wall (Figure 14a). Arteria with a large number of elastic fibres content was also observed (Figure 14b). Sclerotic changes in the wall of the vessel gave positive reactions for neutral and acid mucopolysaccharides (Figure 14c,d).

### 4 | DISCUSSION

The present study revealed that the histological investigation of the vasculature of the different parts of the oviduct of the quail included arteria, venae, lymphatics and blood vessels of the special structure. The integrity of vessels of the oviduct supported its role in reproduction. The summary of the blood vessels of the special structure is showed in Figure 15.

In a 2015 article, Munaff & Baraj explain the blood supply to the oviduct of birds came from cranial, middle and caudal oviductal arteria. Our observation revealed that vessels of different types and sizes were observed at the mesentery of the oviduct. Stratum vascularies were observed on the muscular layer of the different parts of the oviduct.

The oviduct was an immunologically unique part because it can protect itself from foreign pathogens. However, oviduct faced
FIGURE 10  Blood vessels of a special structure were detected within the mesentery of the uterus of the oviduct. (a and b) Vessels of the special structure showed irregular coarse (black asterisks), narrow lumen (black arrow), thick media (black arrowhead) and thin adventitia (white arrowheads) (figure a stained with Crossmon's Trichrome and figure b stained with Harris haematoxylin and eosin). (c) Vein of special type (V) showed smooth muscle fibre at various directions (black arrowheads) and pigment (red arrow) (Crossmon's Trichrome). (d) Spirally oriented arteriola (red asterisk) and lumen (black arrow) (Harris haematoxylin and eosin).

FIGURE 11  Vessels of the stratum vascularies of the uterus of the oviduct. (a) arteria (A), vein (V) and lymphatic vessel (L) (Crossmon's Trichrome). (b) Artery (A) showed increase in collagenous fibrous of the wall (black arrowhead) and narrow lumen (black asterisk) (Crossmon's Trichrome). (c) Positive reactions to PAS in the wall of sclerotic artery (black arrow) (PAS). (d) Atypical glomus vessels (black asterisk) and glomus cells (black arrowhead). (e) Atypical glomus vessels showed spirally oriented coarse (white arrowheads), narrow lumen (black arrowhead) and thick wall (black arrow) (Harris haematoxylin and eosin). (f) Magnification of bordered area in figure (e) showed media formed of inner circular smooth muscle (white arrowheads) surrounded by several layers of glomus cells (red arrowheads) (Harris haematoxylin and eosin).
**FIGURE 12** Arterioles of a special structure on stratum vascularies (a–b and c) and on lamina propria (d) of the uterus of the oviduct. (a) Arteriola with inner circular smooth muscle (black arrow) and glomus cells (black arrowhead) (Harris haematoxylin and eosin). (b) Spirally oriented arteriola with thick wall (black arrowheads) and narrow lumen (black arrow) (Harris haematoxylin and eosin). (c) Arterioles (black asterisk), venulae (black arrow) and dark brown pigment (red arrow) (Harris haematoxylin and eosin). (d) Semithin section of arterioles showed smooth muscle cells (black arrow), elastic fibres (black arrowhead) and glomus cells (white arrowhead).

**FIGURE 13** Stratum vascularies of the vagina of the oviduct. (a) Glomus vessels of typical structure (black asterisk), glomus cells media (black arrow) afferent (black arrowheads) and efferent vessels (white arrowhead) (Crossmon's Trichrome). (b) Dark brown pigmentation closely related to some vessel wall (red arrows) (PAS). (c) Artery of special structure (A) with circularly oriented smooth muscle fibres (black arrow) and patches of longitudinally smooth muscle fibres (white arrowhead) (Harris haematoxylin and eosin).
foreign cells, namely allogeneic spermatozoa. Histological investigation showed several lymphatics with a thin wall and a wide lumen in the different parts of the oviduct of quail. Their wall consisted of an intimal tunic surrounded by fibrous layer. Valves were observed in some of these vessels.

The histological and histochemical examination of the different parts of the oviduct of quail described numerous vessels of special regulatory function in blood flow and pressure regulation (Mohamden, 2009). Adding these vessels attained the regulatory function via the smooth muscle fibres contraction or via the occurrence of glomus cells which swell and decrease in the diameter of the vessels lumen.

Typical and atypical glomus vessels were observed in the current study. According to Mohamden (2009), Mokhtar and Abd-Elhafez (2016), and Hussein and Hassan (2018), the glomus vessels possessed a complex function, including hemodynamic, humeral and thermoregulatory roles. Moreover, the glomus cells in the wall of these vessels were highly reactive special cell and can be divided under certain conditions. In addition, the glomus cell was also observed at our study in the wall of arteria and arterioles. The glomus cells cause the reduction of the luminal diameter of the vessels through its ability to swell or can completely obliterate the lumen.

In oviduct of quail, muscular tunica media of some arteria exhibited inner circular and outer longitudinal or oblique smooth muscle fibres. This may reflect a special structure and play a role in the regulation of blood flow. In addition, some spirally oriented arterioles and venulae with narrowing points along its length were detected in the current study. These vascular devices regulated systemic blood pressure through increasing peripheral resistance to blood flow (Fath-Elbab & Abou-Elhamd, 2016; Mustafa & Abd-Elhafez, 2018).

Physiological sclerotic metamorphoses were observed due to the repeated activity of the oviduct and including extreme thickening of the wall of the vessel, narrowing of the lumen and increase in collagenous and elastic fibrous content. In a 1916 article, Mokhtar & Abd-Elhafez described physiological sclerotic metamorphoses as a series of changes not uniform in distribution and intensity and revealed it to the increase in circulatory demand on the reproductive organs.

Oviduct facilitated the pigment deposition during egg formation causing the eggshell colour (van Brummelen & Bissbort, 1993). Duval-Cassey, Mikšík, Reynolds, and Spencer (2013) mentioned that the protoporphyrin and biliverdin pigment were the two pigments responsible for the egg colour of Japanese quails. According to Liu and Cheng (2010) and El-Desoky (2015), Japanese quails’ egg was pigmented at the uterus.

Our observation revealed that dark brown pigment was observed in the wall of arteria, venae, lymphatics and special types of blood vessels. The pigment was seen on the vessels of magnum, isthmus, uterus and vagina but not seen in the infundibulum. Our data were supported by Keneddy and Vevers (1973) which considered the source of porphyrins pigment not only the uterus but also the blood through erythrocytes disintegration. Moreover, Wang et al. (2009) added that porphyrins and biliverdin pigment were derived from erythrocytes.

5 | CONCLUSIONS

The present study established the description of different vessels of the oviduct of quail; glomus vessels were described; different types of vessels with glomus cells were observed pigment, and vessels’ relation was demonstrated.
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