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The canine hip joint

Thesis submitted by M.N. Peters
To obtain the Diploma
Animal Osteopathy
Supervisor: S. Alen
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Preface

It is my pleasure to present to you the thesis “The Canine Hip Joint”. It has been written to fulfil the graduation requirements to obtain the diploma Osteopathy in animals at ICREO. It is the result of thorough study and research from October 2016 up to April 2017.

I would like to thank my supervisor, Stefan Alen, for all the guidance, support and answers to my questions. Of course I would like to thank Stefan and Frank Dirckx too, for all the lessons and information they gave with enthusiasm.

I would like to thank Dennis Mol, my fiancée, for all the patience, wise words, motivation, and help. Without you I would have been unable to finish this thesis in combination with my work and additional studies.

Marcia Veldboer, thank you for showing me your osteopathic treatments, giving tips about my thesis, and sharing your knowledge.

I also benefitted from debating issues with my friends and family. All of you kept me motivated. My parents deserve a particular note of thanks: your wise counsel and kind words have, as always, served me well.

Piet Mol, thank you very much for your help and comments to my thesis. Your proofreading helped to improve the readability of my work. I appreciate your strong attention to detail.

All horse and dog owners who trusted me while I was practising with their animals, thank you all. And of course I am glad, my own horse and all other animals were as patient with me, while I was learning.

I hope you will enjoy reading this thesis.

Marijke Peters

April 2017.

Index page

Introduction

The hip joint is an important joint in the canine body. It allows the dog to walk, run, and jump, and it carries a part of the body's weight. Yet the hip joint is also one of the most flexible joints and allows a great range of motion. The hip joint is a ball-and-socket synovial joint formed between the os coxae and the femur. Surrounding the hip joint are many tough ligaments that prevent the dislocation of the joint. The strong muscles of the hip region are necessary for movements, and also help to keep the hip joint together. During running and jumping, for example, the force of the body's movements is multiplied on the hip joint. This joint must be able to accommodate these extreme forces repeatedly during intense physical activities.

The description of anatomical structures of the articulatio coxae (art. coxae) can be found in a lot of anatomy books. Books and articles in which osteopathic relationships between structures in animals are explained, are hard to find. An article about the osteopathic vision on the canine hip joint has probably not been written before.

This thesis was written, because of the importance of this joint, and because a lot of people don't know that many structures, not all of which are close to the hip, can affect the dogs hip joint. It is not meant to be a report about how to diagnose a hip dysfunction or pathology, but primarily to show the multiple important aspects of the relations between the hip joint and the rest of the canine body, from an osteopathic point of view.

The purpose of this thesis is to improve the cooperation between trainers, dog owners, therapists, veterinarians and osteopaths; to the advantage of their dogs. For osteopaths, this report can be used as a reference book. For trainers, therapists, vets and owners, this can be an eye-opening thesis, that stimulates to look beyond the local problem.

The research question of this thesis is: Which structures of the canine body can influence the art. coxae? And in which way?
The hypothesis is: osteopathic lesions, insufficient blood supply, some organs (like the urinary bladder, intestines, liver, stomach, kidneys, reproductive organs), muscles (not only the ones which have a function on the hip), fascial restrictions and external factors (like nutrition, sport, trauma, parasites and scars) can be linked to the hip in multiple ways.

In this thesis the osteopathic vision on the influencing structures will be given in clear chapters. The hip joint is, through fascia, in contact with a lot of structures. For easier understanding of the second part, the thesis will start with a few informative chapters about the anatomical structures of the hind limb, thoracic and lumbar vertebrae, and viscera. In the second part, the osteopathic consideration will be described. Osteopathic lesions, arterial influence, and the influence of various organs, fascia, muscles and external factors will be linked to the canine hip joint.

In the conclusion, the research question of this thesis will be answered. The answer will hopefully lead to a different point of view about the canine hip joint.

1. Anatomy

The thesis will start with a chapter about the anatomy of the canine articulatio coxae, vertebrae and viscera, with their muscles, fascia, nerves, veins and arteries. The structures that are necessary for understanding the osteopathic relationships are described here.
First, there will be started with the osteology of the pelvis, femur, sacrum and vertebrae. This will be followed by a chapter about the ligaments and bursae surrounding the canine hip joint. The muscles with influence on the hip joint are described as well.

1.1. Osteology

First the osteology of the canine hip joint and the caudal vertebrae will be described briefly. Figures 1 and 2 are drawings of the canine os coxae and femur. Figure 3 are drawings of the canine vertebrae. They show the anatomy described in the text.

1.1.1. Os coxae

The bony pelvic girdle includes both hip bones (ossa coxae). One os coxae consists of three individual bones (os ilium, os ischium and os pubis), which are completely fused in the adult dog. The ossa coxae of both sides form the ventromedian located symphysis pubica and are separated dorsally by the os sacrum. Together with the sacrum and the first two coccygeal vertebrae, they form the bony pelvis (Reference (Ref.) 1,2,3,4).

The os ilium consists of a corpus ossis ilii and a big dorsal expansion; the ala ossis ilii. Ventrally, this ala ends in the tuber coxae. More mediodorsally this bone merge into the tuber sacrale. Between both, lies the crista iliaca. The crista iliaca is located at the cranial border of the ala ossis ilii and is cartilage-covered. The facies glutea is the surface of origin of the gluteal muscles laterally on the ala ossis ilii. The medial surface of the ala ossis ilii is the facies sacropelvina, which is subdivided into the ear-shaped facies auricularis, for the articulation with the sacrum, and into the dorsally continuing smooth-surfaced fossa iliaca. Ventral of the facies auricularis lies the linea arcuata. At mid-level, the linea arcuata exhibits the very indistinct tuberculum musculi psoas minoris. Opposite to that, on the caudodorsal border of the ala ossis ilii, is the incisura ischiadica major. It provides the passage for the nervus (n.) ischiadicus (Ref. 1,2,3,4).

The os ischium forms the caudal plate of the pelvis. The os ilium is about twice as long as the os ischium. The main part of this bone exists of the tabula ossis ischii. The medial part, conjugating with the os pubis is the ramus ossis ischii. The caudal border merges into a voluminous eminence, the tuber ischiadicum. Both ossa ischii fuse into the symphysis ischiadica. The symphysis ischiadica and the symphysis pubica together are called the symphysis pelvina (Ref. 1,2,3,4). At birth the symphysis pelvina is a firm, fibrocartilaginous, joint. At five years, the two large bones are grown on the midline by an immovable, fused, symphysis (Ref. 5).

The os pubis is the smallest bone of the os coxae. It exists of a corpus ossis pubis, which will participate in the development of the acetabulum. On the cranial border of the ramus cranialis ossis pubis the pecten ossis pubis is formed, where the adductor muscles will attach. On the internal surface of the os pubis the direction of the course of the n. obturatorius can be seen as the sulcus obturatorius. Of the three fused individual bones of the os coxae, the os pubis and the os ischii bound the foramen obturatorium, and both bones fuse with the third, the os ilium, at the acetabulum (Ref. 1,2,3,4).

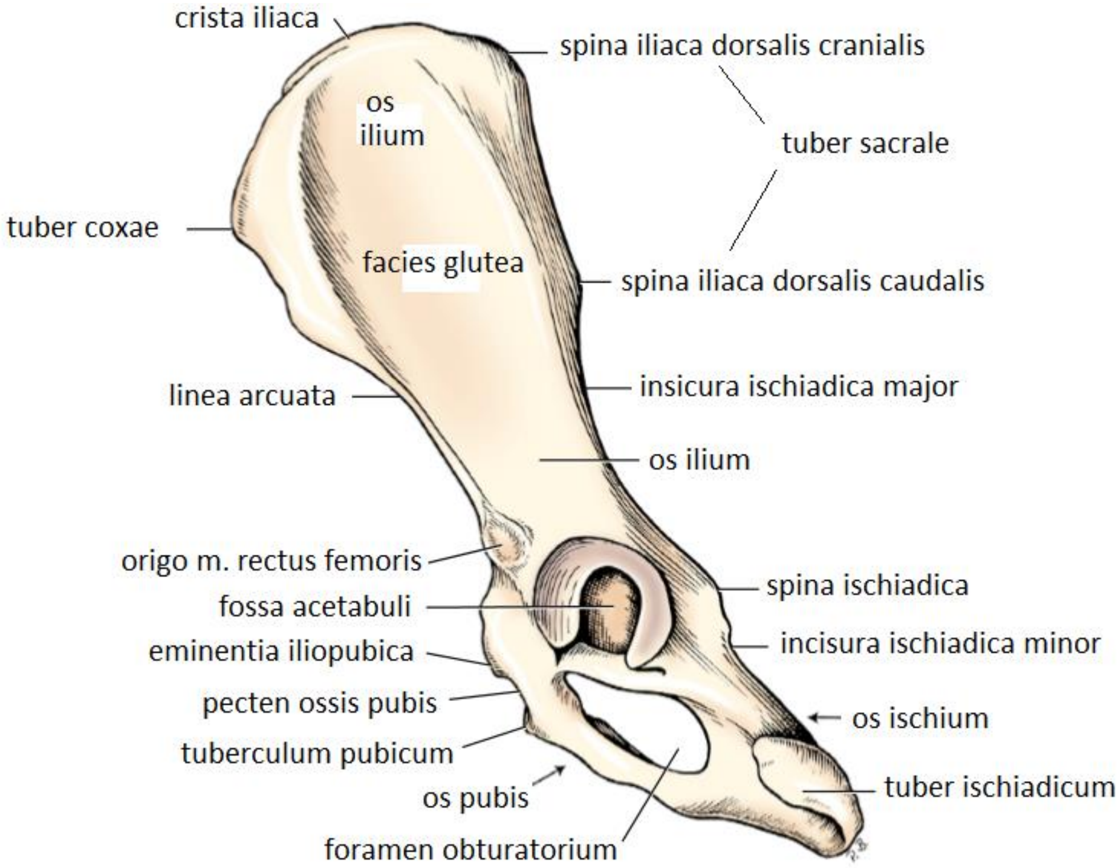


Figure 1 Left hip bone of the dog, lateral view. Source: Evans, Lahunta (2010) p.42

1.1.2. Acetabulum

As written above, the acetabulum is composed of the three different bones of the os coxae. The acetabulum forms the concavity of the hip joint. The caput femoris will form the convexity. In the depth of the acetabulum (fossa acetabuli) of foetuses and puppies a tiny fourth bone is found (os acetabuli) that fuses at an early age with the other components of the os coxae. The surrounding border of the acetabulum is the limbus acetabuli. The incisura acetabuli is a ventromedial interruption of the facies lunata. On the acetabular border the labrum acetabuli is found. It is made up of fibrocartilage and deepens the fossa acetabuli. Cranial of the acetabulum the area musculus (m.) rectus femoris is found, the origo of the concerning muscle (Ref. 1,2,3,4,5).

1.1.3. Femur

Os femoris, the bone of the thigh, is a heavy bone which articulates with the pelvis on one side, and with the tibia on the other. It consists proximally of a head (caput femoris), a thin neck (collum femoris), prominent muscular processes (trochanters) and a body or shaft (corpus femoris) that is continued distally with the trochlea ossis femoris and condylus medialis and lateralis (Ref. 1,2,3,6).

The caput femoris bears an articular surface covered with cartilage except for a small, nearly central area, the fovea capitis, which is the site of attachment of the ligament of the head of the femur (ligamentum (lig.) capitis femoris). The ligament is attached to the acetabulum at the fossa acetabuli. The collum femoris is a distinct narrowing of the bone between the caput and the muscular processes. The lateral process, the trochanter major, is the largest and is the site of attachment of the m. glutaeus profundus and the m. glutaeus medialis. Caudomedial to the base of the trochanter major is the fossa trochanterica, a deep depression that serves for the insertion of deep muscles of the art. coxae. Medial to the fossa trochanterica is the lesser or trochanter minor, which is the insertion of the m. iliopsoas. The tuberositas glutea femoris, or trochanter tertius, is in the dog a small elevation of bone distal to the trochanter major; it is the attachment of the m. glutaeus superficialis (Ref. 1,2,4,6).

The corpus femoris is long and exhibits caudally the facies aspera, which is a rough area for insertion of the m. adductor magnus and m. adductor brevis (Ref. 1,2,4,6).

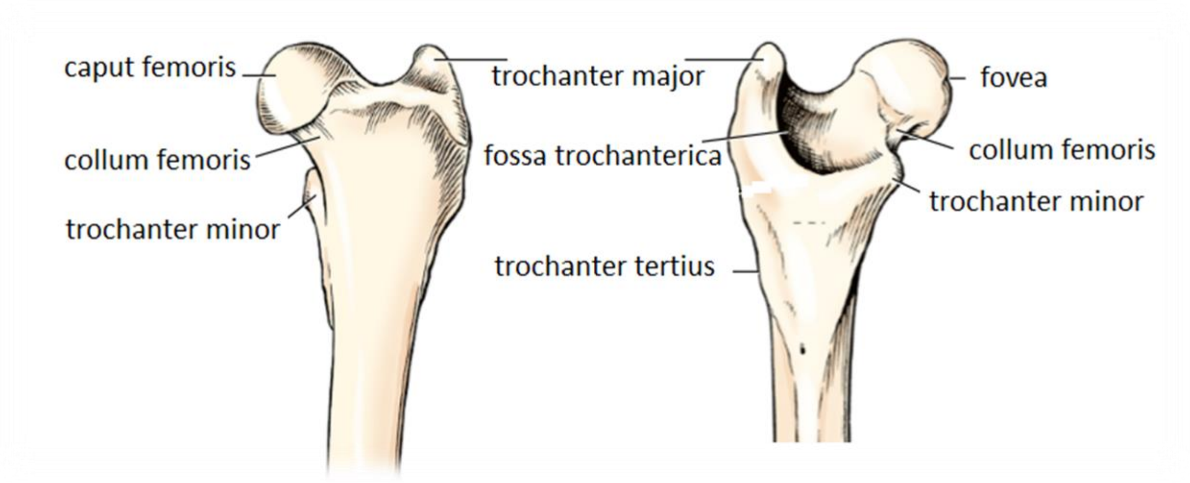


Figure 2 Left femur (proximal part) of the dog, cranial view (left) and caudal view (right). Source: Evans, Lahunta (2010) p.46

1.1.4. The vertebral column

The vertebral column encloses and protects the spinal cord. It has a supporting function with respect to the statics and dynamics of the animal's body. For that, stability is assured by the individual vertebrae, and elasticity as well as movability by the intervertebral symphyses and the vertebral joints. The vertebral column consists of seven cervical vertebrae (C1 – C7), thirteen thoracic vertebrae (T1 – T13), seven lumbar vertebrae (L1 – L7), three sacral vertebrae (S1 – S3), which are fused to form the sacrum, and about twenty caudal (coccygeal) vertebrae (Cy1 – Cy20) (Ref. 1,2,4). In this chapter the anatomy of the vertebrae will be described, with some characteristics of the lumbar and thoracic spine. In the next chapter the os sacrum will be described. See figure 3 for drawings of the lumbar vertebrae.

The vertebrae consist of three basic constituents: corpus and its parts, arcus and processi, that are modified in different ways according to the functional requirements of the particular region (Ref. 1,2,4,7).

The foramen vertebrale is the space enclosed by the corpus and arcus. The canalis vertebralis is formed by the serial foramina vertebralia and the soft tissues extending between the different corpus and arcus vertebrae. It contains the spinal cord with its cauda equina. The foramina intervertebralia are bounded by the incisura vertebralis cranialis and caudalis of the vertebrae of the same and preceding segments; these foramina are passages for the spinal nerves (Ref. 1,2,4,7).

Of the processes of the vertebrae, the processus spinosus is most distinct (exceptions are the first cervical vertebra and the caudal vertebrae). The processus transversi are well developed on the lumbar vertebrae. The processus articularis cranialis and the processus articularis caudalis form synovial joints between the vertebrae. On the thoracic vertebrae, both the foveae costalis caudalis and cranialis form a common articular cavity for the head of the rib (capitulum costae) (Ref. 1,2,4).

In the lumbar vertebral column the ends of the processus transversi represent processus costalis that are remnants of the ribs, and can develop to form lumbar 'ribs.' A processus accessorius is lacking or poorly developed in the caudal part of the lumbar vertebral column. The processus mamillaris of the lumbar vertebrae is expressed on the processus articularis cranialis. (Ref. 1,2,4).

The interarcuate spaces are dorsal and, in life, closed off by ligaments. The lumbosacral space and the sacrococcygeal space are especially wide (Ref. 1).

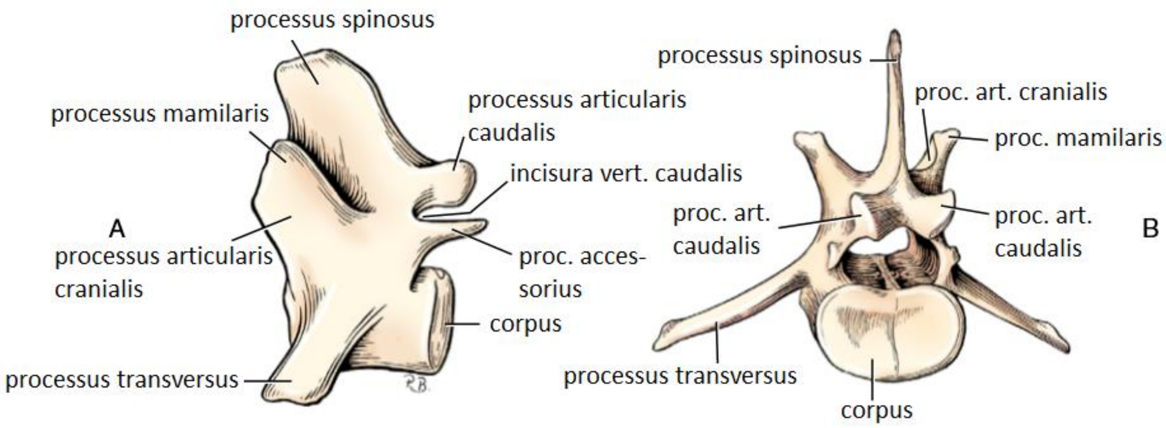


Figure 3 A. Fourth lumbar vertebra of the dog, left lateral view. B. fifth lumbar vertebra of the dog, caudolateral view. Source: Evans, Lahunta (2010) p. 78

1.1.5. Os sacrum

The sacrum of the dog is formed by the fusion of the three sacral vertebrae. Laterally, it bears the ala ossis sacri, whose facies auricularis forms a synovial joint with the facies auricularis of the os ilium. The crista sacralis mediana is formed by an incomplete fusion of the processus spinosi at the facies dorsalis of the sacrum. Lateral of the crista sacralis mediana the foramina sacralia dorsalia are found; the places where the dorsal radices of the accompanying nervi spinales will exit. The facies pelvina is the ventral side of the sacrum. Here can the foramina sacralia pelvina be seen; places where the ventral radices of the nervi (nn.) spinales will exit. The promontorium forms the cranioventral contour of the os sacrum, which will articulate with the last lumbar corpus vertebrae. The apex ossis sacri is the caudal part of the sacrum. Here the os sacrum will articulate with the first vertebrae of the tail (Ref. 1,2,4,7).

1.2. Artrology

1.2.1. The hip joint

The hip joint, or art. coxae, is a joint between the acetabulum and caput femoris. It is a spheroidal joint (ball-and-socket joint), which is the most freely movable type of synovial joint. This shape means that all movements are possible: extension, flexion, abduction, adduction, endorotation, exorotation and circumduction. It is surrounded by ligaments, bursae and a capsula articularis (Ref. 1,2,4,5).

The acetabular labrum is a ring of cartilage that surrounds the acetabulum of the hip. The labrum resists lateral and vertical motion of the femoral head within the acetabulum by deepening the joint; and thus provides stability. Besides, researchers showed that the labrum provides a seal around the femoral head and restricts fluid flow into and out of articular space. This “suction effect” of the labrum and fluid enhances joint stability and distributes compressive loads between articular surfaces, which reduce peak cartilage stresses during weight bearing. It has been established that the labrum plays a critical role in cartilage preservation (Ref. 8).

The acetabulum and the caput femoris are covered with hyaline cartilage. The cartilage is tooth-shaped with the bone attached, its surface is smooth and glossy. Nutrition of the cartilage layer is provided by synovia, and by diffusion from the capillaries of the membrana synovialis on the other hand. Its function is to distribute forces and pressure, and to minimal friction (Ref. 1,2,4,5,9).

The synovia, or synovial fluid, is a viscous egg white–like consistency. The principal role of synovial fluid is to reduce friction between the articular cartilage of the joints during movement (Ref. 1,2,4,5,9). Below, in chapter 1.2.2- 1.2.4, a description of the capsula articularis, ligaments, and bursae is given.

1.2.2. Capsula articularis

The capsula articularis is strong and dense. It covers the acetabulum and the caput femoris till the collum femoris. It is connected to the lig. transversum acetabuli and to the outer margin of the labrum. The more slight bands of fibers in the fibrous joint capsule will help to limit movement in this joint. The capsula articularis is consolidated by ligaments. The external surface of the capsule is rough, covered by muscles. (Ref. 1,3).

The capsule consists of two layers or membranes; an outer (membrana fibrosa) and an inner (membrana synovialis). The outer layer is composed of avascular white fibrous tissue. The outer layer is highly innervated by the same nerves which perforate through the neighbouring muscles associated with the joint. It is made up of dense irregular connective tissue, thus ensuring the stability of the joint is increased (Ref. 9).

The membrana synovialis contains elastic fibers, blood vessels and nerves. Plicae articulares and villi articulares are found in the membrana synovialis too.The membrana synovialis makes direct contact with the synovial fluid, which it is primarily responsible for maintaining. In contact with the synovial fluid at the tissue surface are many rounded macrophage-like synovial cells (type A) and fibroblast-like (type B) synovial cells. Type A cells maintains the synovial fluid by removing wear-and-tear waste and type B cells produces hyaluronan among other extracellular components in the synovial fluid (Ref. 9).

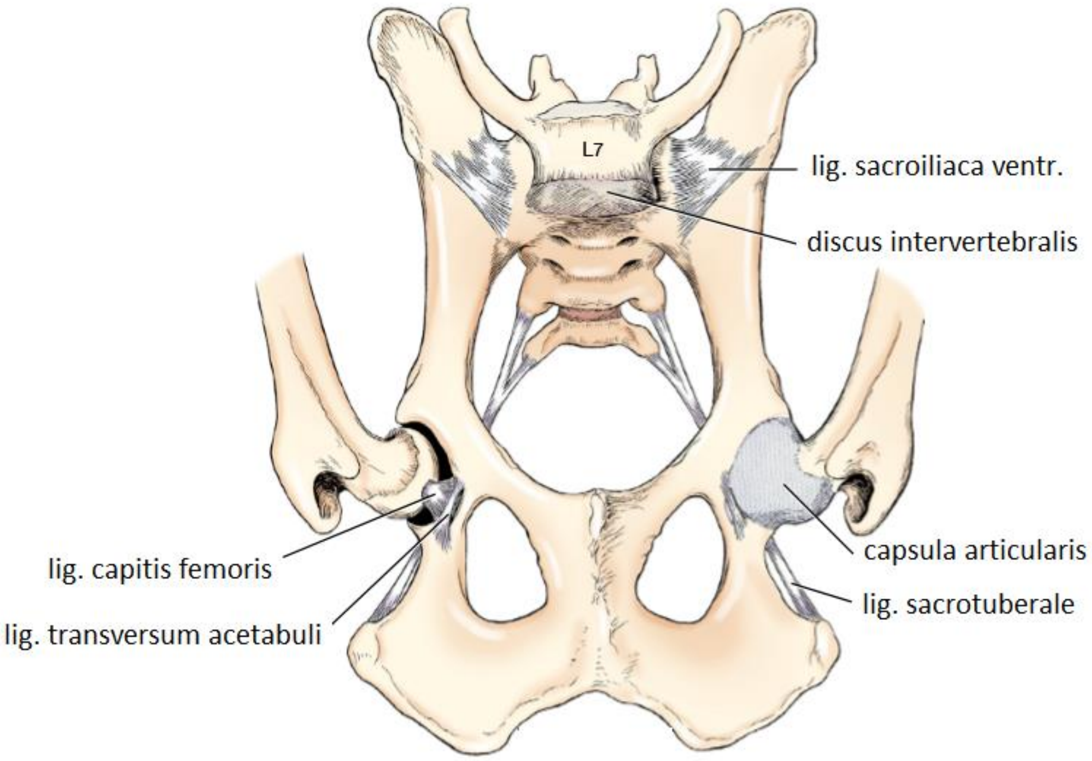


Figure 4 ligaments and capsula articularis of the canine pelvis and hip joint, ventral view. Source: Evans, Lahunta (2010) p. 71

1.2.3. Ligaments of the hip joint

Numerous conventional anatomical textbooks describe the canine hip joint, but many contradictions, in particular regarding the lig. capitis femoris, are present (Ref. 10).

At the hip joint the lig. transversum acetabuli bridges over the incisura acetabuli, and the labrum of the acetabulum (Ref. 1,4,10).

The lig. capitis femoris is a short but very strong ligament. In some textbooks it is also called lig. teres. Each of the possible movements in the hip is limited by this ligament. Through this ligament goes an artery (arteria (a.) epiphysialis) which provides the blood supply to the femoral head. Its origo is in the fossa acetabuli, its insertion is in the fovea capitis femoris, according to most anatomy books (Ref. 1,4,10). See figure 4 for a drawing of the lig. capitis femoris, lig. transversum acetabuli and the capsula articularis of the hip joint, according to Evans and Lahunta (2010). This corresponds with most anatomy books.

Casteleyn et al. (2015) did research about the ligaments in the canine hip. To this purpose, the hip joints of 41 dogs were examined. According to Casteleyn et al. (2015) it was observed that the lig. capitis femoris is not a single structure that attaches only to the fossa acetabuli, as generally accepted, but it also connects to the lig. transversum acetabuli and is complemented by a strong lig. accessorium (Ref. 10). This lig. accessorium courses in caudal direction to attach in the elongation of the fossa acetabuli that extends on the cranioventral surface of the body of the os ischium. The description of this lig. accessorium in conventional anatomical handbooks is incomplete, according to Casteleyn et al. (2015) (Ref. 10). However, the data found in their research isn't confirmed by other researches yet.

1.2.4. Synovial bursae

Bursae are closed fibrous sacs, lined with a smooth membrane, producing a viscous lubricant known as synovial fluid. Bursae are found in regions where muscles or tendons rub against other muscles, tendons, or bones. The bursae function in two ways, lubricating points of friction, and dissipating force by distributing it through a fluid medium (Ref. 11).

The bursa ischiadicum of the m. obturator internus lies between the muscle and the incisura ischiadicum minor. The bursa trochanterica of the m. glutaeus superficialis is present in about one-third of all dogs. It is located between the insertion tendon of the muscle and the trochanter major. The bursa trochanterica of the m. biceps femoris is found between the muscle and the tendon of insertion of the m glutaeus superficialis (Ref. 5).

1.2.5. The sacroiliac joint

The joint between the sacrum and the ilium of the os coxae is called art. sacroiliaca. This is the joint that joins the skeleton of the pelvic limb to the axial skeleton. It is a synovial joint but virtually very little movement occurs owing to strong dorsal, ventral, and interosseous sacroiliac ligaments. The articular surfaces of sacrum and ilium bear a thin layer of cartilage whose planar surfaces are complementary. With such limited movement, the joint capsule is tight (Ref. 1,2,3,4).

1.3. Nervous and circulatory system

1.3.1. Nervous system

The nervous system is the part of an animal's body that coordinates its actions and transmits signals to and from different parts of its body. It consists of two main parts, the central nervous system (CNS) and the peripheral nervous system (PNS). The CNS consists of the brain and the spinal cord. The PNS is divided into the somatic and autonomic nervous system. The autonomic nervous system is further subdivided into the (ortho)sympathetic and the parasympathetic nervous systems (Ref. 1,12,13).

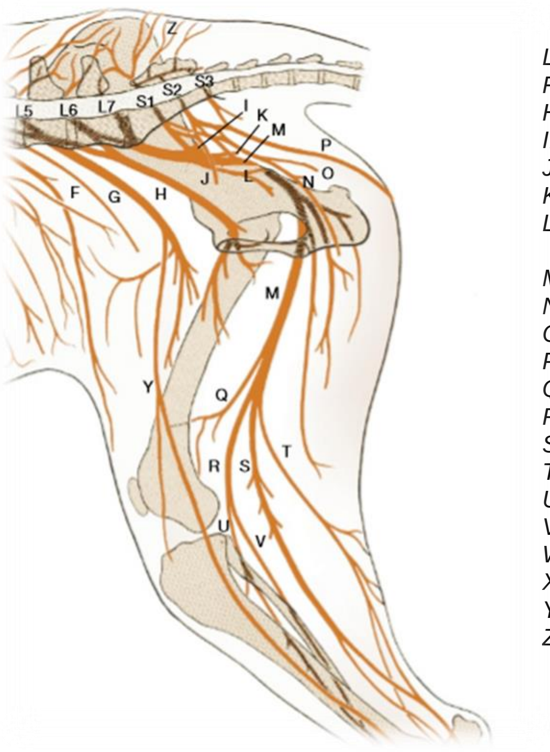
The axial part of the orthosympathetic nervous system is limited to the thoracic and lumbar spinal cord. The preganglionic neurons travel to ganglia in several floors, and the postganglionic fibers are often long. The functions of this system are those of activity and of energy consumption. It increases the heart rate, and makes vasoconstriction and increase in blood pressure possible. Instead, it lowers the tone of the smooth muscles in the digestive, respiratory and the urogenital system. It activates the endocrine secretions, especially in the adrenal glands. It increases the sweat production and assess pilo-erection. Finally, it causes the opening of the pupil and admitting more light into the eye (Ref. 1,12,13).

Nerve fibres of the parasympathetic nervous system include the cranial nerves, and the spinal nerves in the sacrum (the pelvic splanchnic nerves). The preganglionic fibers of the peripheral part may be very long; they reach into the vicinity of the viscera, or make contact with them; this is the only ganglionnaire level. The postganglionic fibers are short. In general, their functions are the opposite of the orthosympathetic nervous system: rest, sleep, saving and restoring energy. It slows down the heart, it increases the tone of the smooth muscle cells of the viscera, and the peristalsis, as well as the secretions in the gastro-intestinal system and the respiratory system. It reduces the amount of light penetrating the eye pupil by constriction. Finally, it also activates emptying of the pelvic organs (Ref. 1,12,13).

The short description above is based on the unanimous findings of numerous studies, but it masks some uncertainties. Both systems, the orthosympathetic and parasympathetic system are basically no opposites. Both work continuously together to optimize functioning of the organism. They are controlled simultaneously by the higher centers in the brains, which intervene by simply adjusting the respective tones (Ref. 13).

For this thesis, the n. vagus is the most important cranial nerve, because this nerve is in contact with viscera which can be linked to the hip joint. This nerve will be described below.

The n. vagus, or tenth cranial nerve, carries both sensory and motor fibers from and to the viscera. About 20 percent are visceral motor fibers (preganglionic parasympathetic efferent fibers), and about 80 percent are visceral sensory fibers (afferents from all of the thoracic and most of the abdominal organs). The dorsal branches unite near the diaphragm to form the dorsal vagal trunk. The ventral branches unite caudal to the root of the lung to form the ventral vagal trunk. The ventral vagal trunk supplies the liver, the parietal surface of the stomach, and the pylorus. The dorsal vagal trunk gives off a coeliac branch that passes dorsocaudally and contributes to the formation of the plexus coeliacus and plexus mesenterica cranialis. These abdominal aortic plexuses are nerve networks lying on, around, and passing along abdominal vessels after which they are named. The plexuses supply the musculature of the artery and arterioles, and the viscera supplied by the branches of that artery. The abdominal aortic plexuses include the plexus coeliacus, mesenterica cranialis, mesenterica caudalis, renalis and hypogastricus. These plexuses contain sympathetic visceral efferent processes and numerous visceral afferent processes (Ref 1,4,12).



Legend:
F. n. genitofemoralis
H. n. obturatorius
I. n. glutaeus cranialis
J. n. pelvicus
K. n. glutaeus caudalis
L. To m. obturator internus, mm. gemelli, and m. quadratus femoris
M. n. sciaticus
N. n. pudendus
O. n. perineus
P. n. femoralis cutaneous caudalis
Q. n. cutaneous lat. Suralis
R. n. peroneus communis
S. n. tibialis
T. n. cutaneous caudalis suralis
U. n. peroneus profundus
V. n. peroneus superfiscialis
W. n. plantaris lat.
X. n. plantaris med.
Y. n. saphenous
Z. Dorsal branches of lumbar and sacral nerves

Figure 5 Schematic medial view of right lumbar and sacral nerves. Source: Evans, Lahunta (2010) p. 199

1.3.2. Nerves of the hind limb

The plexus lumbosacralis is diffuse and consists of the ventral branches of the lumbar and sacral spinal nerves. The n. obturatorius arises from the fourth, fifth, and sixth lumbar spinal nerves. It is formed within the caudomedial portion of the m. iliopsoas. It leaves the muscle dorsomedially, runs caudoventrally and leaves the pelvis by passing through the cranial part of the foramen obturatorium. It supplies the adductor muscles of the limb: the m. obturatorius externus, m. pectineus, m. gracilis, and the m. adductor (Ref. 1,12).

The n. femoralis arises primarily from the fourth, fifth, and occasionally the sixth lumbar spinal nerves. Within the m. iliopsoas the n. saphenous arises from the cranial side of the n. femoralis. The n. saphenous or n. femoralis innervates the m. sartorius. The cutaneous portion of the n. saphenous supplies the skin on the medial side of the thigh, the stifle, leg, tarsus, and remainder of the paw. The n. femoralis enters the m. quadriceps between the m. rectus femoris and m. vastus medialis and supplies all four heads of the m. quadriceps. It is responsible for stifle extension to support weight in the pelvic limb (Ref. 1,12).

The ventral branches of the sacral nerves emerge from the two pelvic foramina sacralia and the foramen intervertebrale to form the sacral plexus. The n. pudenda arises from all three sacral nerves. It passes caudolaterally, where it lies lateral to the m. levator ani and m. coccygeus, medial to the m. glutaeus superficialis (Ref. 1,12). See figure 5 for a detailed schematic view of the nerves in the hind limb of the dog. In the chapters about the muscles of the hind limb, the nerves innervating the concerning muscles are described a bit more detailed.

1.3.3. Arteries

The circulatory system is composed of the heart, arteries, capillaries, veins and lymphatic vessels. The blood moves from the left atrium, to the left ventricle, to the systemic arteries, to the capillary beds of the body, to the systemic veins, to the right atrium, to the right ventricle, to the pulmonary arteries, to the capillary beds of the lungs, to the pulmonary veins and then again to the left atrium, to renew the circle (Ref. 4). In this chapter, the arteries in the hind limb of the dog will be described briefly.

The arteries carry blood from the heart and, except for the pulmonary trunk and arteries, contain blood rich in oxygen. Blood traversing the spleen, pancreas, stomach and intestines is not carried back directly to the heart but passes through the portal vein to the liver (Ref. 1,12,14). See the figures below for a detailed schematic view of the arteries and veins in the hind limb.

In the hind limb, the aorta divides into the a. iliaca interna and a. iliaca externa. The a. iliaca externa runs further to the paw, where its name is changed into a. femoralis, a. poplitea and a. tibialis (cranialis and caudalis) (Ref. 1,12,14).

The a. glutealis caudalis is the larger of the two terminal branches of the a. iliaca interna. It arises opposite the sacroiliac joint and passes to the m. coccygeus, parallel to the a. pudenda interna. The a. glutealis cranialis is a branch of the a. glutealis caudalis. The a. glutealis cranialis and nerve pass across the cranial part of the incisura ischiadica major of the ilium and between the m. glutaeus medius and m. glutaeus profundus, which they supply. The a. iliolumbalis arises close to the origin of the a. glutealis caudalis or directly from the a. iliaca interna. It passes across the cranioventral border of the ilium and supplies the m. psoas minor, m. iliopsoas, m. sartorius, m. tensor fasciae latae, and m. glutaeus medius (Ref. 1,12,14).

The right a. iliaca externa arises from the aorta on the level of the sixth and seventh lumbar vertebrae. It runs caudoventrally and is related laterally near its origin to the common vena (v.) iliaca and the m. psoas minor. Farther distally it lies on the m. iliopsoas. The a.

iliaca externa becomes the a. femoralis at passing through the abdominal wall. The opening through which the a. iliaca externa passes is the lacuna vasorum, located between the caudal border of the aponeurosis of the m. obliquus externa (lig. inguinale) and the pelvis. The a. femoralis courses caudally (Ref. 1,12,14).

Through the lig. capitis femoris goes the a. epiphysialis which provide the blood supply to the femoral head (Ref. 1).

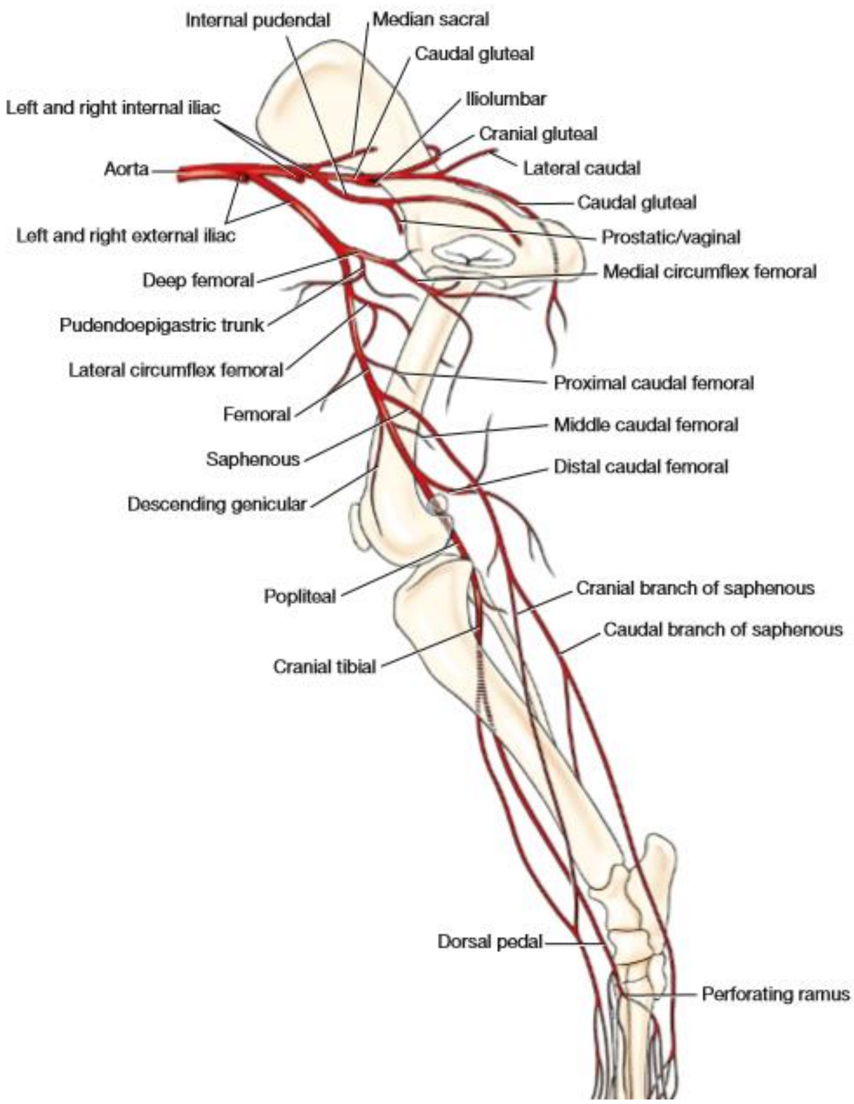


Figure 6 Arteries of right pelvic limb, schematic medial view. Source: Evans, Lahunta (2010) p. 188

1.3.3. Veins

Through the venous system, the (mostly) oxygen poor blood will continue in the direction of the heart. The vena cava caudalis is formed by the v. iliaca interna and externa from the left and from the right. The v. iliaca externa is called the v. femoralis distally. It gives of the v. femoralis profunda branch. The v. poplitea divides into the v. tibialis caudalis and v. tibialis cranialis (Ref. 1,12,14).

The v. saphenus lateralis originates in the popliteal region from the v. caudalis femoralis distalis. It divides in the distal third of the crus into a cranial branch and a caudal branch. The cranial branches of the v. saphenus lateralis and medialis anastomose under the knee joint, on the flexor aspect of the tarsus. From their union the large common trunk of vv. digitorum dorsalis communis II – IV is formed. The caudal branches of the v. saphenus lateralis and medialis also anastomose proximal to the plantar tarsus. Each vein continues distally. The caudal branch of the v. saphenus lateralis is large. It runs distally on the lateral plantar aspect of the hock and, at the level of the proximal border of the metatarsal pad, forms the venous arcus plantaris superfiscialis. It is this arch that receives vv. digitorum plantaris communis II – IV (Ref. 1,12,14).

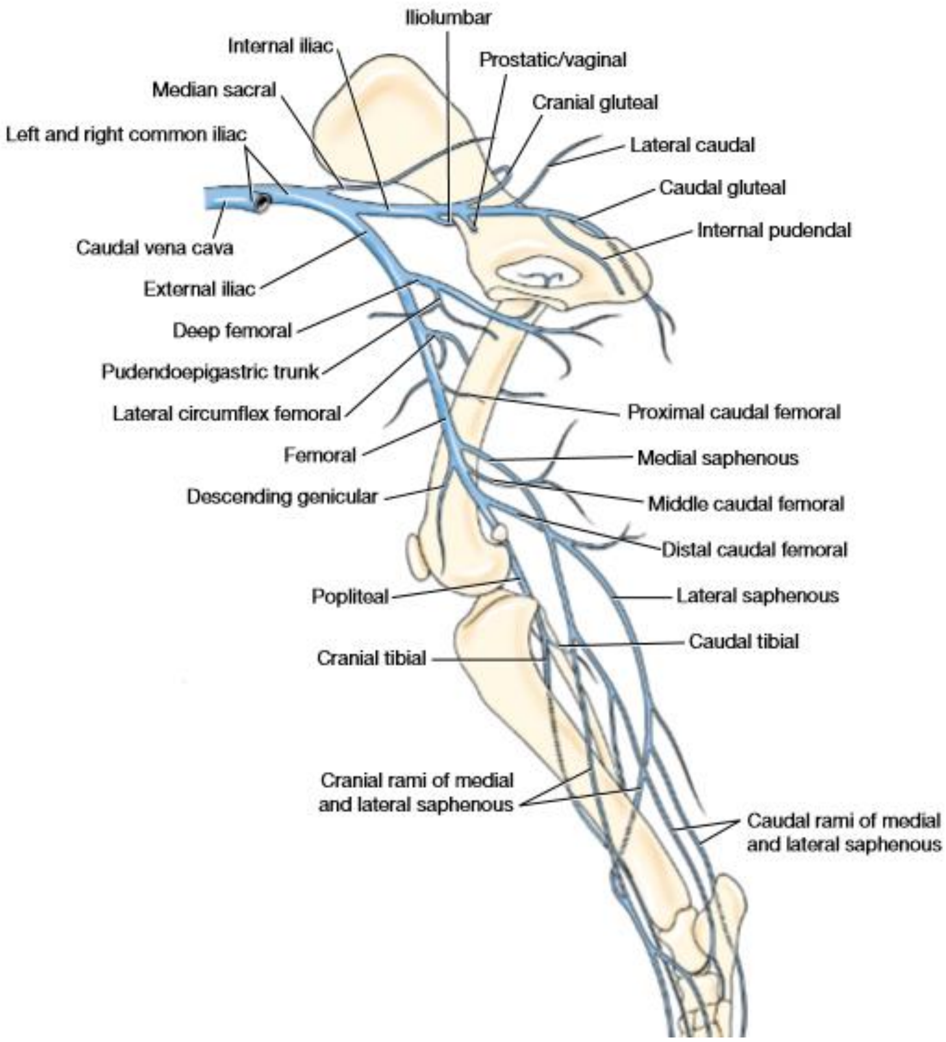


Figure 7 Veins of right pelvic limb, schematic medial view. Source: Evans, Lahunta (2010) p. 189

1.3.5. Lymph vessels

The lymph vessels begin distally in the region of the digits and the digital and metatarsal pads with a well-developed net of lymphatic capillaries. From the distal region of the pelvic limb the superficial lymph vessels go to the lymphonodus (ln.) popliteus superfiscialis that lies in the popliteal region between the m. biceps femoris and m. semitendinosus. After that, the superficial lymph vessels run predominantly to the ln. inguinalis superfiscialis and from there through the canalis inguinalis to the ln. iliacus medius. The deep lymph vessels also reach the ln. popliteus and from there in a variable manner to the ln. iliacus medius. On the one hand they course in company with the nn. tibialis and ischiadicus to the ln. sacralis and from there to the ln. iliacus medius. Otherwise they pass with the a. and v. femoralis and by way of the femoral space the inconstant ln. iliofemoralis, and finally the ln. iliacus medius. From the lymphonodi (lnn.) iliacus medius the lymph flows to the cisterna chyli and may pass by way of the lnn. lumbalis aorticus. The cranial continuation of the cisterna chyli is the ductus thoracicus, which transports the lymph to the venous angle between the v. jugularis externa and interna (Ref. 1,12,14).

1.4. Myology

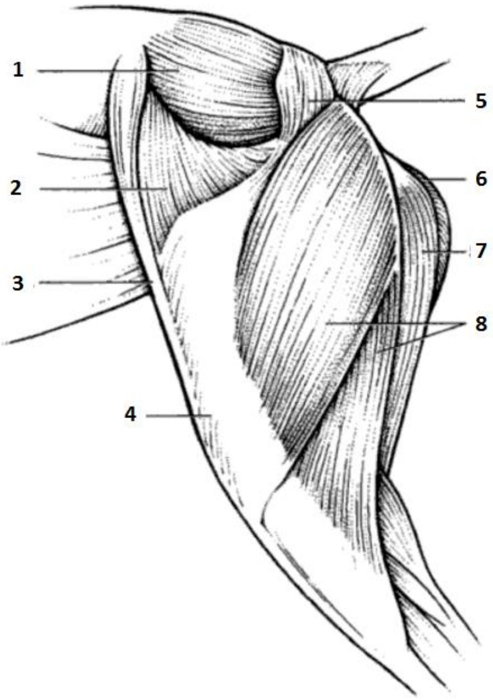
The sacroiliac joints and symphysis pelvis can move very little, so the muscles that pass from the axial skeleton to the pelvic limb have very little effect on these joints. In contradiction, the hip is a joint which is movable in all directions (Ref. 5). The muscles with a function on the canine hip joint will be described in detail in this chapter. Also the innervation of these muscles will be described.

1.4.1. M. tensor fasciae latae and m. quadriceps femoris

The m. tensor fasciae latae originates at the tuber coxae and neighboring part of the os ilium and radiates with its cranial main portion into the superficial lamina of the fascia lata, which fuses distally with the lig. patellae (m. quadriceps tendon). Its caudal, fan-shaped, part passes over into the deep portion of the fascia lata, that ends on the lateral lip of the rough area of the femur (facies aspera ossis femoris). Function: tensor of the fascia lata and flexor of the hip joint. Nerve supply: n. glutaeus cranialis (Ref. 1,2,15). See figure 8 for a drawing of this muscle.

The m. quadriceps femoris consists of the m. vastus lateralis, m. vastus intermedius and m. vastus medialis, which originate proximally from the femur, and of the m. rectus femoris, which originates craniodorsal to the acetabulum at the spina iliaca ventralis caudalis. Owing to its origin from the bony pelvis, the m. rectus femoris can act as an extensor of the stifle joint and at the same time as a flexor of the hip joint. This in contradiction to the three other heads, which only have a function on the knee (extension). The strong tendon of insertion of the m. quadriceps femoris invests the patella and terminates with the lig. patellae (or tendo m. quadricipitis) on the tuberositas tibiae. Here the insertion tendon is underlain by a bursa infrapatellaris (Ref. 1,2,15).

The m. quadriceps femoris is innervated by the n. femoralis. The n. femoralis in the abdominal region is embedded in the m. iliopsoas and courses together with it through the lacuna musculorum. It then emerges from the ventral surface of the m. iliopsoas. Here it gives off the n. saphenus, which supplies the stifle joint and runs as a sensory nerve on the medial surface of the limb distally to the first and second digits (Ref. 1,2,15).



Legend:
1. *M. glutaeus medius*
2. *M. tensor fasciae latae*
3. *Cranial belly of the m. sartorius*
4. *Fascia lata*
5. *M. glutaeus superficialis (aponeurosis cut)*
6. *M. semimembranosus*
7. *M. semitendinosus*
8. *M. biceps femoris*

Figure 8 superficial muscles of the left lateral pelvic region and thigh, lateral view. Source: Smith (1999) p.532

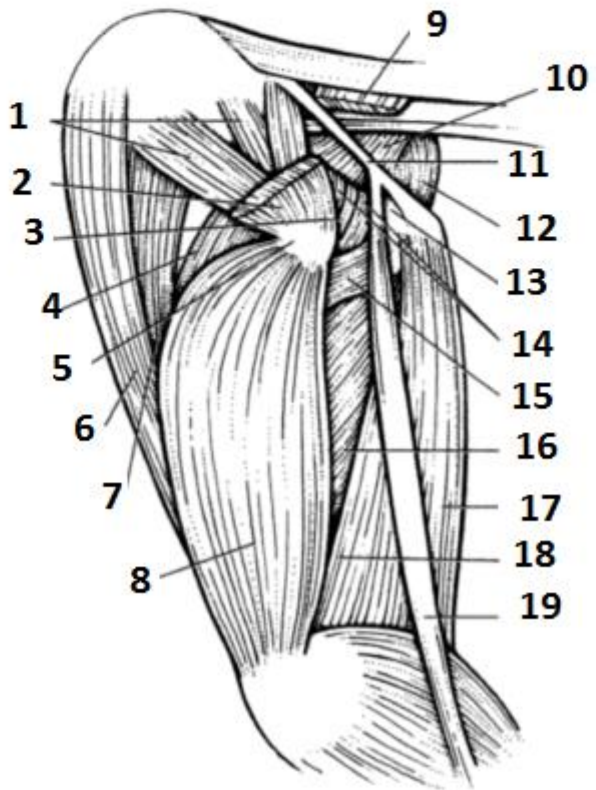
1.4.2. Croup muscles

The croup muscles arise from the facies glutea of the os ilium (m. glutaeus medius and m. glutaeus profundus) or from the sacrum and lig. sacrotuberale (m. piriformis and m. glutaeus superficialis). All croup muscles end on the trochanter major of the femur. Function: extension of the hip joint and abduction of the limb (Ref. 1,2,15). See figure 8, 9 and 10 for drawings of these muscles).

The m. glutaeus profundus turns the cranial face of the thigh medially. The m. glutaeus superficialis lies most caudally and terminates most distally at the base of the trochanter major on the tuberositas glutea (just below the m. glutaeus medius attachment). The m. glutaeus medius originates dorsally at the facies glutea. Some authors make a distinction between the m. periformis and the m. glutaeus medius. According to Henning (1965) the m. piriformis lies deep to the m. glutaeus medius and ends jointly with it on the caudal part of the trochanter major of the femur (Ref. 1,2,15).

The m. glutaeus profundus has an extended area of origin between the ventral and caudal linea glutea. Its fibers converge to insert on the cranial part of the trochanter major (Ref. 1,2,15).

Innervation of the croup muscles is by the nn. glutaeus cranialis and caudalis, both of which emerge at the insicura inschiadica major. The n. glutaeus caudalis enters the medial aspect of the m. glutaeus superficialis and in exceptional cases also the m. piriformis (when this muscle is distinguished from the m. glutaeus medius). The n. glutaeus cranialis passes between the m. glutaeus profundus and the m. glutaeus medius. It supplies these muscles and, usually, the m. piriformis, and a branch passes through the lateral part of the m. glutaeus profundus to end in the m. tensor fasciae latae (Ref. 1,2,15).



Legend:

1. *M. gluteus profundus*
2. *M. gluteus medius (cut)*
3. *Tendon of the m. obturator internus*
4. *M. rectus femoris*
5. *Trochanter major*
6. *Cranial belly of the m. sartorius*
7. *Caudal belly of the m. sartorius*
8. *M. vastus lateralis*
9. *M. coccygeus (cut)*
10. *M. levator ani*
11. *Lig. sacrotuberale*
12. *External anal sphincter*
13. *Tuberositas ischiadicum*
14. *Mm. gemelli*
15. *M. quadratus femoris*
16. *M. adductor*
17. *M. semitendinosus*
18. *M. semimembranosus*
19. *M. abductor cruris caudalis*

Figure 9 deeper muscles of the left lateral pelvic region and thigh, lateral view. Source: Smith (1999) p.533

Legend:

1. *M. gluteus profundus*
2. *Tendon of the m. obturator externus*
3. *Tendon of the m. obturator internus*
4. *Mm. gemelli*
5. *M. obturator internus*
6. *Foramen obturatorium*

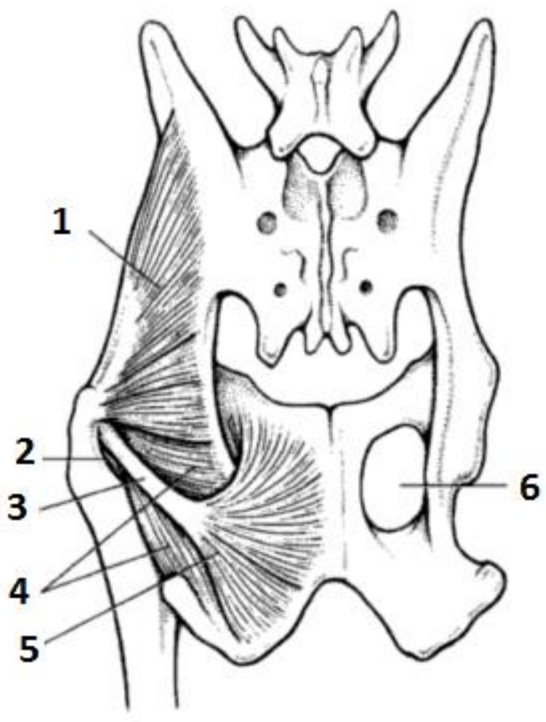


Figure 10 deeper muscles of the dorsal pelvic girdle, dorsal view. Source: Smith (1999) p.534

1.4.3. Hamstrings muscles

The hamstrings muscles are the m. biceps femoris, m. semitendinosus, and m. semimembranosus (See figure 8 and 9 for drawings of these muscles). They arise from the tuber ischiadicum and additionally (m. biceps femoris) from the neighboring part of the lig. sacrotuberale. The m. abductor cruris caudalis, which may be described with this group, has its origin only from the lig. sacrotuberale. Function: extension of the hip joint, flexion of the stifle joint, and also extension of the hock joint insofar as they end in a tractus calcaneus, or tendo accessorius (m. biceps femoris and m. semitendinosus) (Ref. 1,2,15).

The m. biceps femoris terminates with a broad aponeurosis on the lig. patellae (m. quadriceps tendon), the tuberositas tibiae and on the fascia cruris. Moreover, it terminates on the tuber calcanei by the tractus calcaneus lateralis, which at the distal third of the crus fuses with the tractus calcaneus medialis from the m. semitendinosus and m. gracilis. After section of the m. biceps femoris, it becomes clear that the tractus calcaneus lateralis gets a fascial reinforcement from the lateral lip of the facies aspera of the femur (and it is for this reason that the term ‘tractus’ is used instead of ‘tendon’). The straplike m. abductor cruris caudalis originates from the distal part of the lig. sacrotuberale, deep to the m. biceps femoris, and its insertion radiates into the fascia cruris with the caudal border of the m. biceps femoris. The caudo-laterally located m. semitendinosus ends proximo-medially on the tibia and, together with the tendon of the m. gracilis, is continued by the tractus calcaneus medialis. The caudo-medially placed m. semimembranosus has two strong muscle bellies. The cranial one terminates on the condylus medialis femoris, and the caudal one distal to the art. femorotibialis on the condylus medialis tibialis (Ref. 1,2,15).

The innervation of the hamstrings is by muscular branches that proceed from the proximal part of the n. ischiadicus, which ends at midthigh by dividing into the n. tibialis and the n. peroneus communis. The cranial part of the m. biceps femoris originates from the lig. sacrotuberale and receives additionally a branch of the n. gluteus caudalis (thus the term gluteobiceps may correctly be used to designate the m. biceps femoris). The m. abductor cruris caudalis is innervated by a musculocutaneous branch of the n. peroneus communis. After the muscular branch is given off, this small nerve ends as a cutaneous branch. Proximal to its branching, the n. ischiadicus crosses the insicura inschiadica major, and then passes over the neck of the femur where the neck is covered by the deep muscles of the hip joint. It innervates the hip joint and divides between the m. biceps femoris and m. adductor magnus into the strong n. tibialis and the smaller n. peroneus communis. The division of the n. ischiadicus into n. tibialis and the n. peroneus communis becomes distinct only in the distal half of the thigh; because, in the proximal thigh, the two nerves are held together in a common connective tissue envelope (Ref. 1,2,15).

1.4.4. The deep hip joint muscles of the obturator group

The four deep hip joint muscles of this group are: the musculi (mm.) gemelli, the m. obturatorius internus, the m. obturatorius externus, and the m. quadratus femoris. They turn the cranial face of the thigh (and limb) laterally, so they make external rotation. The origin of the deep muscles of the hip joint is from the os coxae near the foramen obturatorium. Their insertion is in the fossa trochanterica of the femur and (m. quadratus femoris only) just distal to the fossa on the caudal surface of the femur (Ref. 1,2,15). See figure 10 for drawings of these muscles.

The mm. gemelli originate in the region of the insicura inschiadica minor and bound on the caudal border of the m. gluteus profundus. The m. obturatorius internus has its origin internally on the medial border of the foramen obturatorium and passes with a strong tendon dorsal to the mm. gemelli, which form a central sulcus where the tendon passes over them. The m. obturatorius externus has a similar area of origin on the medial border of the foramen obturatorium, but it lies externally on the bony pelvis. From this muscle, only a more deeply located strong terminal tendon is visible at the caudal border of the mm. gemelli (Ref. 1,2,15).

The m. quadratus femoris begins ventromedially at the tuber ischiadicum and ends at the distal border of the fossa trochanterica. Innervation is by the muscular branches of the n. ischiadicus, which originates at the caudal border of the m. gluteus profundus from the n. ischiadicus. An exception is the m. obturatorius externus, which is supplied only by the n. obturatorius (Ref. 1,2,15).

1.4.5. Adductor muscles

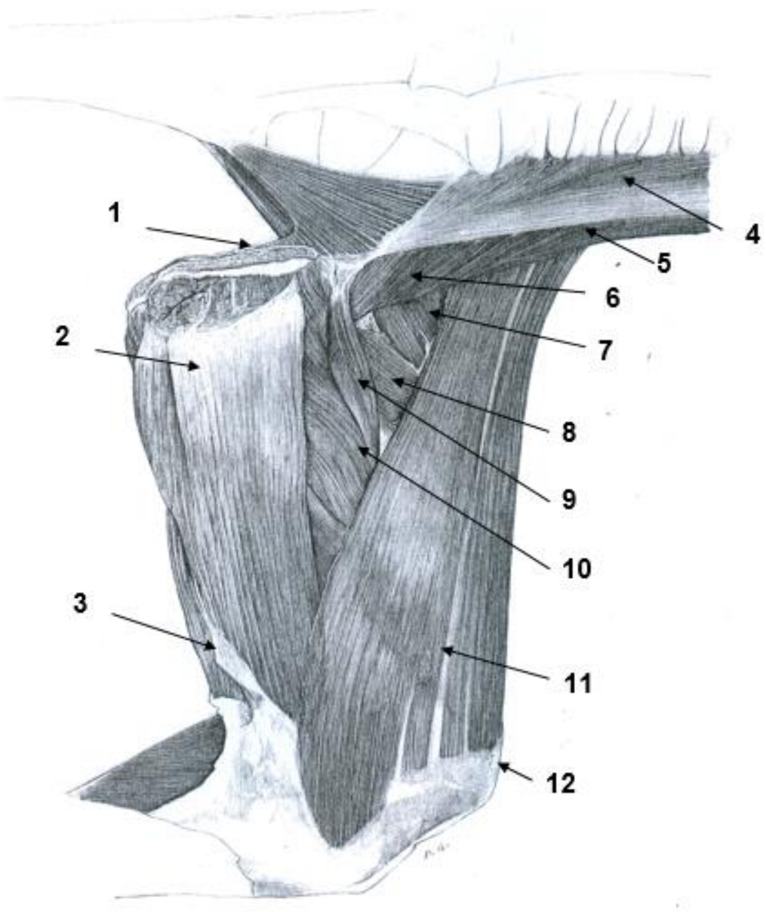
The adductor muscles are the m. sartorius, the m. gracilis, the m. pectineus and the m. adductor magnus and brevis. The m. pectineus must be considered as a double muscle according to its phylogenetic development, because in the dog it is fused with the m. adductor longus. The muscle originates at the eminentia iliopubica and ends at the medial border of the femoral shaft to the distal epiphysis (Ref. 1,2,15). See figure 11 for a drawing of these muscles.

The m. sartorius is split into a cranial and a caudal part, which originate at the crista iliaca and, respectively at the cranial margin of the ala ossis ilii, and radiate into the medial femoral and crural fasciae. Function: adduction of the limb and extension of the stifle joint. After release of the n. saphenus, the n. femoralis supplies the m. sartorius and the four heads of the m. quadriceps femoris. The branch to the m. sartorius may arise from the n. saphenus (Ref. 1,2,15).

The m. gracilis originates with the m. gracilis from the other side in a symphysical tendon, at the symphysis pubica and ischiadica. The insertion of this muscle is at the distal half of the medial tibia by a common tendon with the m. semitendinosus and m. sartorius and, by its tarsal tendon, which joins that of the m. semitendinosus, the tuber calcanei. The function of this muscle is, just like the other adductor muscles, adduction (Ref. 1,2,15).

The m. adductor magnus originates in an extended area from the lateral surface of the symphysial tendon and from the os pubis and os ischium along the symphysis pelvina. It has a broad-surfaced ‘fleshy’ insertion at the facies aspera of the femur. The m. adductor brevis arises from the ventral tuberculum pubicum and ends, together with the m. adductor magnus, proximally on the facies aspera. It can be identified on the basis of a typical nerve branch that crosses over the m. adductor brevis before it enters the m. adductor magnus (Ref. 1,2,15).

The n. obturatorius courses on the internal surface of the pelvis, through a gap of the m. levator ani and, following in the sulcus obturatorius of the os pubis, continues to the foramen obturatorium. It passes through the foramen obturatorium, supplies the m. obturator externus and gives off muscular branches for the adductor muscles of the thigh (m. adductor magnus, m. adductor brevis, m. pectineus). Emerging medially between the m. pectineus, it enters the deep surface of the m. gracilis, which is also innervated by the n. obturatorius. The nerve ends medially at the stifle joint with a very weak sensory branch (Ref. 1,2,15).



Legend:
1. *m. obturator internus*
2. *m. gracilis*
3. *m. semitendinosus*
4. *m. psoas minor*
5. *m. psoas major*
6. *m. iliacus*
7. *m. rectus femoris*
8. *m. vastus medialis*
9. *m. pectineus*
10. *m. adductor*
11. *m. Sartorius*
12. *patella*

Figure 11 musculature of the left thigh, medial view. Source: Horowitz (2010)

1.4.6. Deep hip flexors

In this group the psoas muscles are found, including the m. quadratus lumborum and the m. iliacus. The m. psoas major and the m. iliacus are sometimes called m. iliopsoas together. The muscles are located ventrolateral to the lumbar vertebral column and are supplied by ventral branches of the lumbar nerves (Ref. 1,2,15). See figure 12 for a drawing of these muscles.

The m. quadratus lumborum originates at the last three thoracic vertebrae and the processus transversus of the lumbar vertebrae and courses to its region of insertion, which extends from spina alare to the facies auricularis of the os ilium. The function of this muscle is flexion of the lumbar spine, or lateroflexion (unilateral) (Ref. 1,2,15).

Not all authors of canine anatomy books agree with each other completely, about the origin and insertion of the m. psoas major. According to Budras, McCarthy, Fricke and Richter (2007), the m. psoas major arises from the vertebral ends of ribs 12 and 13, and the processus transversus of the cranial lumbar vertebrae (Ref. 1). According to Nickel, Schummer and Seiferle (2003), the origin of the m. psoas major is the vertebral end of the last one *or* two ribs, the last one or two thoracic vertebrae, and from the lumbar vertebrae (Ref. 2). According to Evans and de Lahunta (2010), the m. psoas major only arises from the processus transversus and bodies of lumbar vertebrae. They do not mention the thoracic vertebrae or ribs (Ref. 12).

All authors agree, that at the level of the pelvis, the m. psoas major joins the m. iliacus to form the m. iliopsoas. The m. iliacus takes origin from the facies iliaca of the ilium and from the lateral surface of the insertion tendon of the m. psoas minor. The m. iliopsoas traverses the lacuna musculorum to insert at the trochanter minor of the femur. The m. psoas major lies retroperitoneal in the celiac in contact with the kidneys and viscera. Its function is flexion, adduction and exorotation of the hip when the spine is punctum fixum (the non-moving part of the joint) and the femur is punctum mobile (the moving part of the joint). When the femur is punctum fixum, the muscle provides flexion of the lumbar spine, or unilateral lateroflexion. The m. iliacus has mostly the same function. The only difference is that the m. iliacus by a fixated limb makes anteversion of the pelvis (Ref. 1,2,15).

The m. psoas minor arises from the last two or three thoracic and first four or five lumbar vertebrae (here the authors are not entirely in agreement too), where it lies ventral to the m. psoas major. It terminates with a flat tendon at the tuberculum m. psoas minor of the ilium, in the middle of the linea arcuata. Its function is lateroflexion of the lumbar spine, and retroversion of the pelvis. This muscle has no direct function on the limb (Ref. 1,2,15).

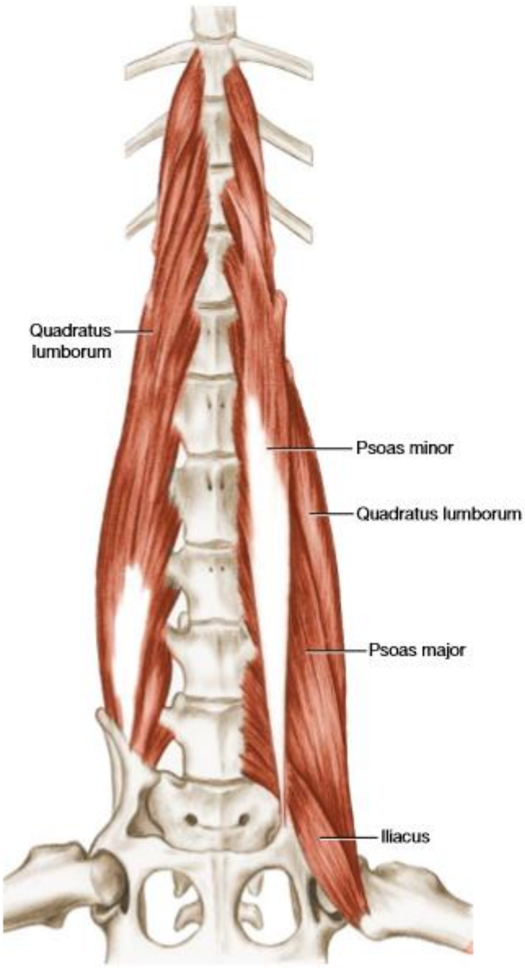


Figure 12 Sublumbar muscles, deep dissection, ventral aspect. Source: Evans, Lahunta (2010) p. 62

1.4.7. Diaphragm

The diaphragm and the m. phrenicus, which is the diaphragm muscle, will also be described in this chapter. This muscle isn't in direct contact with the hip, but because of its osteopathic importance, and possible osteopathic relation with the hip joint, the diaphragm will be discussed.

The diaphragm is a dome-shaped musculotendinous plate which forms the separation between the thoracic and abdominal cavity. The V-shaped central part (centrum tendineum) consists of tendinous tissue. The centrum tendineum is surrounded and spanned by a muscle, the m. phrenicus. The m. phrenicus consists of three parts: pars sternalis, pars costalis and pars lumbalis (Ref. 1,12,16).
The pars lumbalis of the diaphragm is formed by the crus dexter and crus sinister. They have their origin on the ventral side of the third and fourth lumbar vertebrae and continue in cranioventral direction. The crus dextrum is heavier and continues further in the centrum tendineum than the crus sinistrum. Both crura form the psoas arcade. Under this arcade the m. psoas major, m. psoas minor, the truncus sympathicus and nn. splanchnici are running (Ref. 1,12,16).

The costal part of the diaphragm arises from the medial surfaces of the eighth to thirteenth ribs, alternating with the origin of the m. transversus abdominis. The sternal part is narrow and arises from the dorsal surface of the sternum cranial to the xiphoid cartilage. The cupula is the most cranial extent of the dome-shaped diaphragm that bulges into the thorax (Ref. 1,12,16).

The convex side, (or cranial side, thoracic side) of the diaphragm is lined with parietal pleura and the fascia endothoracica. In the mediastum the heart is located. Its apex is resting on the diaphragm dome. The concave side, (caudal side or abdominal side) is coated with the fascia transversalis and the parietal peritoneum. This is in contact with the liver, the spleen, the kidneys, and various parts of the colon. The diaphragm is innervated by the n. phrenicus. This is a spinal nerve that generally is formed from the ventral branches of the cervical nerves. In canines the phrenic nerve arises from C5-C7 with occasional small contributions from C4 (Ref. 1,12,16).

The diaphragm has three openings through which pass various structures:

- The hiatus aorticus is a dorsal passageway between the crura for the aorta caudalis, v. azygos and ductus thoracicus.
- The more centrally located hiatus esophagus is in the muscular part of the right crus and transmits the esophagus, vagal nerve trunks, and esophageal vessels.
- The foramen vena cava is located at the junction of the tendinous and muscular parts of the right side of the diaphragm. The caudal vena cava passes through it (Ref. 1,12,16).

A contraction of the m. phrenicus causes a displacement inferiorly which increases the thoracic cavity. When the animal makes inspiration, the centrum tendineum is stretched by the contraction of the surrounding muscles. The ribs will expand especially latero-lateral. The thoracic cavity is enlarged, and the lungs will expand passively. Upon expiration, relaxation of the diaphragm, the ribs and the centrum tendineum will go back into their previous position, assisted by the elasticity of the lungs. The existing air is pressed out of the lungs and the thoracic cavity is smaller again (Ref. 1,12,16).

Also, the diaphragm has an important function as abdominal press too. This is of importance during defecation, urination and pressing during birth (Ref. 1,12,16). See figure 13 for schematic illustrations of the dogs diaphragm.

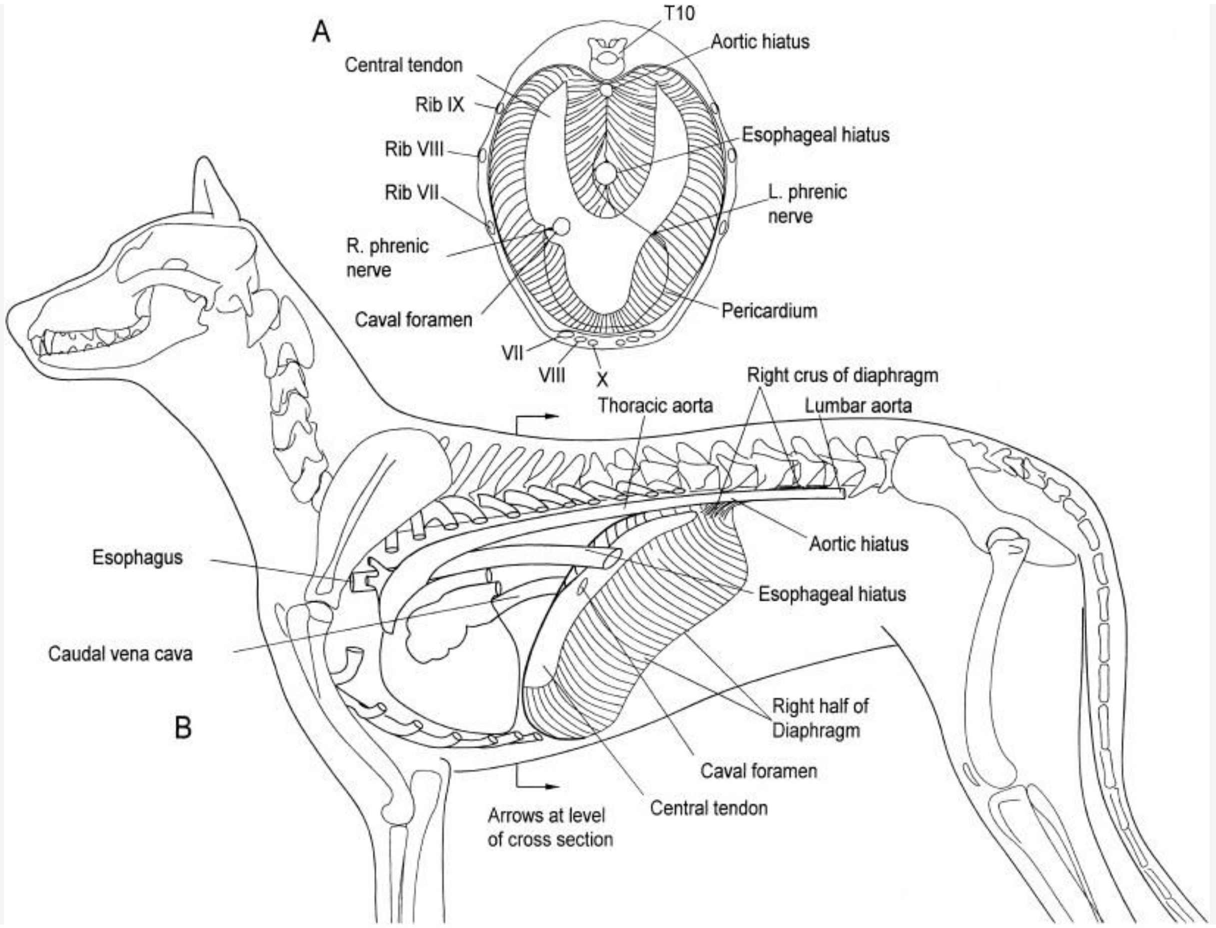


Figure 13 Schematic illustrations of the dogs diaphragm. A: Cranial view of the dogs diaphragm. B: Left lateral schematic view of the dogs diaphragm, cut along the midline. Source: https://www.researchgate.net

1.5. Fascia

Every body structure is wrapped in connective tissue, or fascia, creating a structural continuity that gives form and function to every tissue and organ. The body must be considered as a functional unit, where every area is in communication with another through the fascial continuum. Medical literature does not suggest a sole definition of fascia, because it varies in terms of thickness, function, composition, and direction depending on its location. The fascial tissue is equally distributed throughout the entire body, enveloping, interacting with, and permeating blood vessels, nerves, viscera, meninges, bones, and muscles, creating various layers at a variety of depths, and forming a tridimensional metabolic and mechanical matrix. The fascia becomes an organ that can affect an individual’s health (Ref. 17,18,19,20,21). Fascia is classified by layer, as subcutaneous fascia or deep fascia, or by its function and anatomical location (Ref. 19).

1.5.1. Subcutaneous and deep fascia

The most external layer of fasciae is named subcutaneous fascia or connective fascia, and is the layer that primarily determines the shape of a body. This layer is made up of several levels, each with variable amounts of fibroblasts and soaked in a gelatinous substance known as extracellular matrix. This superficial layer is not located exclusively under the skin, but it permeates the entire body, enveloping the organs and forming the neurovascular branches, and the various fasciae of the muscle districts, finally resting on the deep fascia. It is also found at many other locations where it fills otherwise unoccupied space. It serves as a storage medium of fat and water; as a passageway for lymph, nerve and blood vessels; and as a protective padding for damping and isolation. Due to its viscoelastic properties, superficial fascia can stretch to accommodate the body. After pregnancy and weight loss, the superficial fascia slowly reverts to its original level of tension (Ref. 18,19,20,21).

The superficial fascia is made up of different layers, whose formation facilitates the sliding of one layer over another. The number of layers of the superficial fascia, and the amount of substances they contain depend on the quantity of fat, the sex, and the body area concerned. The various layers communicate by a micro system, which is in turn composed of the same structures of the superficial fascia; it is a microscopic web, containing vessels and nerves, in varying directions, and is highly deformable (Ref. 17,18,19,20,21).

The deep fascia is the last connective layer before coming in contact with the somatic structure (i.e., bones and muscles), and the visceral and vascular systems. It is characterized by various levels of loose connective tissue. Its vascular and lymphatic system is well developed, with numerous corpuscles in charge of proprioception, particularly the Ruffini's and Pacini's corpuscles. It is a less extendable fibrous layer, with collagen fibers arranged more regularly, thick and parallel to each other; it is rich in hyaluronic acid. Examples of deep fascia are fascia lata and fascia cruris (Ref. 17,18,19,20,21).

According to some authors, the fascial layer enveloping the organs is a serous fascia, others call it the prolongation of the deep fascia. The organs have specialized names for their fascia. For example, the meninges refer to the fascial coverings of the brain and spinal cord. The fascia covering the heart is called pericardium; the fascial structures covering the lungs are called pleurae; and in the abdomen, the peritoneum refer to the fascial structures covering the viscera. Visceral fascia is less extensible than subcutaneous fascia. Due to its suspensory role of the organs, it needs to maintain its tone rather consistently. If it is too lax, it contributes to organ prolapse, yet if it is hypertonic, it restricts proper organ motility (Ref. 21).

All fascial layers contain a variable amount of fibroblasts with the ability to contract, known as myofibroblasts. They contain a type of actin similar to the one traceable in the muscles of the digestive system; i.e., alpha-smooth muscle actin. Scientific research has proven that the fascial continuum is innervated by the autonomic sympathetic system. Fasciae are normally thought of as passive structures that transmit mechanical tension generated by muscular activities or external forces throughout the body. The function of muscle fasciae is to reduce friction of muscular force. In doing so, fasciae provide a supportive and movable wrapping for nerves and blood vessels as they pass through and between muscles. Fascial tissues are innervated by sensory nerves. Based on this a proprioceptive, nociceptive as well as interoceptive function of fascia has been postulated. Fascial tissues - particularly those with tendinous or aponeurotic properties - are also able to store and release kinetic energy (Ref. 17,18,19,20,21).

Fascia becomes important clinically when it loses stiffness, becomes too stiff or has decreased shearing ability. When inflammation or trauma causes fibrosis and adhesions, fascial tissue fails to differentiate the adjacent structures effectively. This can happen after surgery where the fascia has been incised and healing includes a scar (Ref.21).

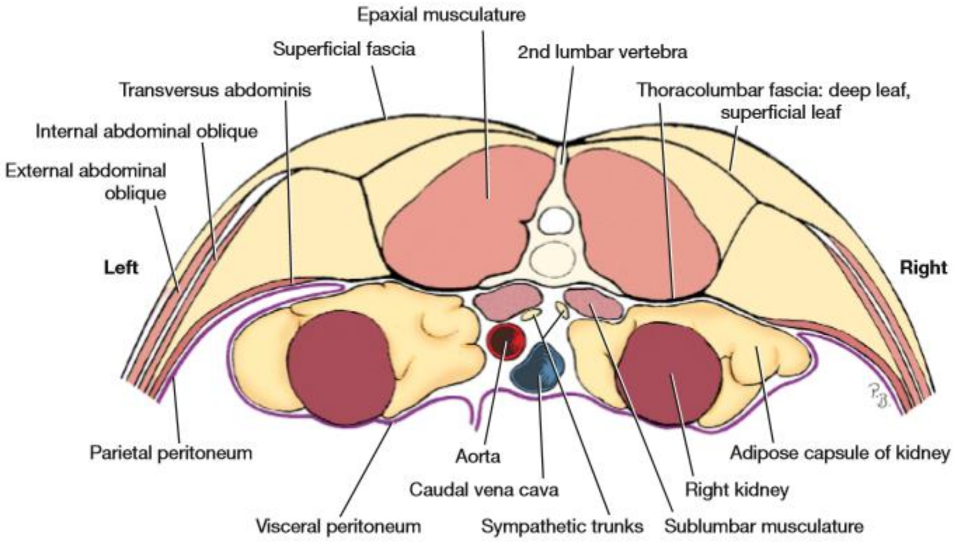


Figure 14 Schematic transection in the lumbar region showing fascial layers. Source: Evans, Lahunta (2010) p. 51

1.5.2. Fascial structures in the pelvic limb

The fascia thoracolumbalis is a deep investing membrane throughout most of the posterior thorax and abdomen. It is continued with a similar investing layer on the back of the neck- the fascia nuchalis. It is formed of longitudinal and transverse fibers that bridge the aponeuroses of the m. obliquus internus, m. obliquus transversalis, angulus costae, and the crista iliaca laterally, to the vertebral column and sacrum medially. In doing so, they cover the paravertebral muscles (Ref. 12,18). See figure 14 for a drawing of the fascial layers in the lumbar region.

The fascia thoracolumbalis makes the connection of the posterior and the anterior side of the body. Through the fascia thoracolumbalis, the force of the hind leg is transferred to the forehand. The junction of this force transmission is located in the thoracolumbar region. The fascia thoracolumbalis is a very firm structure, especially in the lumbar region. It originates in the crista sacralis medialis, the tuber sacralis, the crista iliaca, and the tuber coxae. Caudally it continues into the fascia glutaea. The m. latissimus dorsi, m. gluteaeus medius, m. spenius and the m. serratus dorsalis caudalis/ cranialis are connected to the fascia thoracolumbalis with their aponeuroses. The mm. erector spinae, m. quadratus lumborum, and psoas muscles are in contact. The fascia is in contact with the lig. supraspinale of the lumbar and thoracic spine. Via the lig. supraspinale, lig. interspinale and lig. flavum, the fascia is connected to the facet joints of the spinal column (Ref. 2,12,18). This is shown in the figure on the next page (figure 15).

The fascia iliaca covers the mm. psoas minor and major, and m. iliacus. Topside it is thin, but thickens progressively towards the lig. inguinale. Medially, the fascia is attached to the intervertebral discs, vertebral bodies, and the upper part of the sacrum. The fascia iliaca is continued as the lig. inguinale and the fascia transversalis. Medially it becomes the fascia pectinea, attached to the pecten ossis pubis and the capsule of the hip joint. It thus forms a septum between the lig. inguinale and the hip, dividing this space into a lateral part, the lacuna musculorum, containing m. psoas major, m. iliacus and the n. femoralis, and a medial part, the lacuna vasorum, transmitting the a. iliaca and v. saphena. In addition, the fascia iliaca surrounds the lumbar plexus. Its strength increases from cranial to caudal, because here it holds the psoas muscles dorsally to the lumbar vertebrae, the os ilium, and fixes them anterior to the iliosacral joint. Due to the relationship between psoas muscle group, caecum, kidney, ureter and colon, the fascia iliaca can also be given an important role in osteopathy (Ref. 2,22).

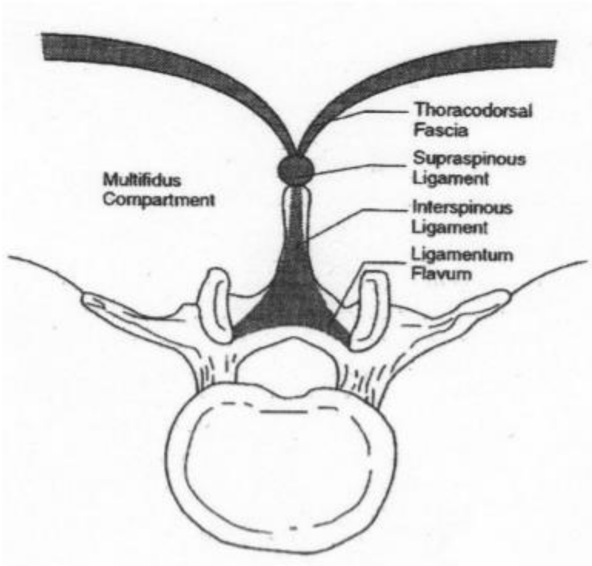


Figure 15 The connection between the fascia thoracolumbalis and the spine. Source: ICREO 3.3. Alen (2017) p.12

As indicated above, the fascia iliaca is continued as fascia transversalis. This fascia covers the internal surface of the m. transversus abdominis, and continues over the abdominal surface of the diaphragm. Both fascia (left and right) are connected to each other at the linea alba. In the inguinal region it helps to build the fascia spermatica. This may be important in the healing after a castration. On the inside it is in contact with the parietal layer of the peritoneum (Ref. 2,22).

The superficial fascia of the gluteal region is the fascia glutea. It passes from the fascia thoracolumbalis and, in the direction of the femur, is continued as the fascia lata, which is tensed by the m. tensor fasciae latae. The fascia femoralis medialis covers the m. tensor fasciae latae, m. rectus femoris, m. vastus medialis, m. satorius, m. gracilis, m. semimembranosus and m. semitendinosus. Laterally this fascia passes into the fascia lata. At the inner aspect of the thigh, proximal to the knee, the fascia femoralis medialis receives the aponeuroses of the m. gracilis and the m. sartorius, and then continues into the fascia genus and fascia cruris (Ref. 2,22).

1.5.3. Peritoneum

Like the other serous membranes the peritoneum consists of a parietal and a visceral layer. The first one is the peritoneum parietale that covers the internal surface of the abdomen and continues till the pelvic cavity. The peritoneum viscerale is the layer that covers the abdominal and pelvic organs to which it is intimately connected (Ref.18).

These membranes circumscribe the peritoneal cavity, a vast but virtual space by the fact that the organs are lying in contact with each other or in contact with the wall. The peritoneum makes them mobile. These movements are facilitated by the small amount of serous fluid (peritoneal fluid) (Ref.18).

In general, the most important organs are attached to the lumbar wall; the liver and part of the stomach are attached to the diaphragm. Finally, the rectum and the caudal parts of the urinary and genital system (retroperitoneal position) are fixed to the sacrum and pelvis.

Connective tissue, like the peritoneum, contains smooth muscles, which puts it under the influence of the sympathetic nervous system. The vascularisation of the abdominal organs runs through the serous layers of the peritoneum, and will thus be reduced by peritoneal tension (Ref.18). See figure 16 for a schematic drawing of the peritoneum.

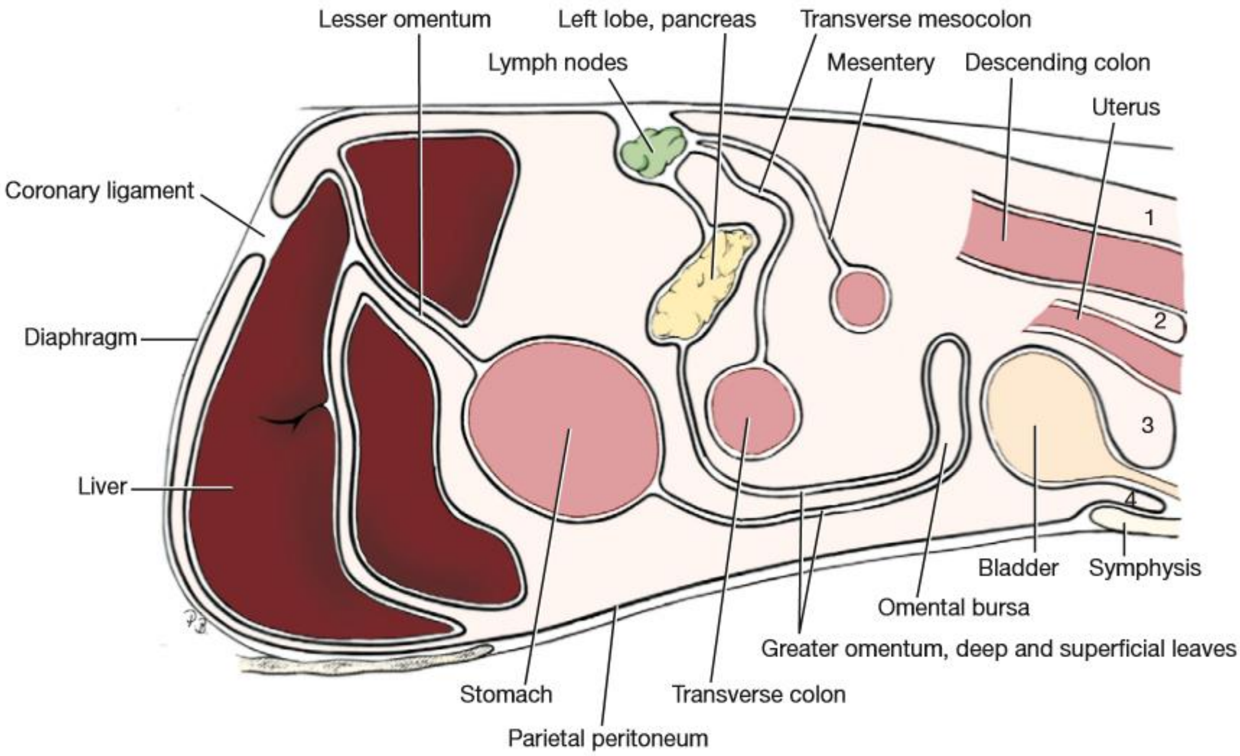


Figure 16 Peritoneum of the dog, sagittal section. Source: Evans, Lahunta (2010) p. 144

1.6. Viscera

In this chapter the viscera of the dog will be discussed. The viscera with a relation to the hip joint are included here. These are the kidneys, intestines, reproductive organs, bladder, and the liver. A short description of the adrenal glands is included too, because in the osteopathic chapters there will be referred to these organs. The relations with the hip will be discussed in the osteopathic part.

1.6.1. Kidneys

The kidneys are bean-shaped organs. Their main function is to regulate the balance of electrolytes in the blood, along with maintaining pH homeostasis. They also remove excess organic molecules from the blood: the removal of waste products of metabolism (Ref. 1,23,24).

Kidneys are essential to the urinary system and also serve homeostatic functions such as the regulation of electrolytes (including salts), maintenance of acid–base balance, maintenance of fluid balance, and regulation of blood pressure (via the salt and water balance). They serve the body as a natural filter of the blood, and remove water-soluble wastes which are diverted to the bladder. In producing urine, the kidneys excrete nitrogenous wastes such as urea and ammonium. They are also responsible for the reabsorption of water, glucose, and amino acids. The kidneys also produce hormones including calcitriol and erythropoietin. An important enzyme, renin, is also produced in the kidneys; it acts in negative feedback (Ref. 1,23,24).

The kidneys lie retroperitoneally within the retroperitoneal space. The left kidney lies ventral to the first three lumbar vertebrae and the right kidney a half vertebral length more cranial. The superior pole of the right kidney is adjacent to the liver. For the left kidney, it's next to the spleen (Ref. 1,23,24).

The kidney has a convex and a concave border. A recessed area on the concave border is the hilum renale, where the a. renalis enters the kidney and the v. renalis and ureter leave. The kidney is surrounded by tough fibrous tissue, the capsula renalis, which is itself surrounded by perirenal fat (capsula adiposa), renal fascia, and pararenal fat (corpus adiposum pararenale). The anterior surface of these tissues is the peritoneum, while the posterior surface is the fascia transversalis (Ref. 1,23,24).

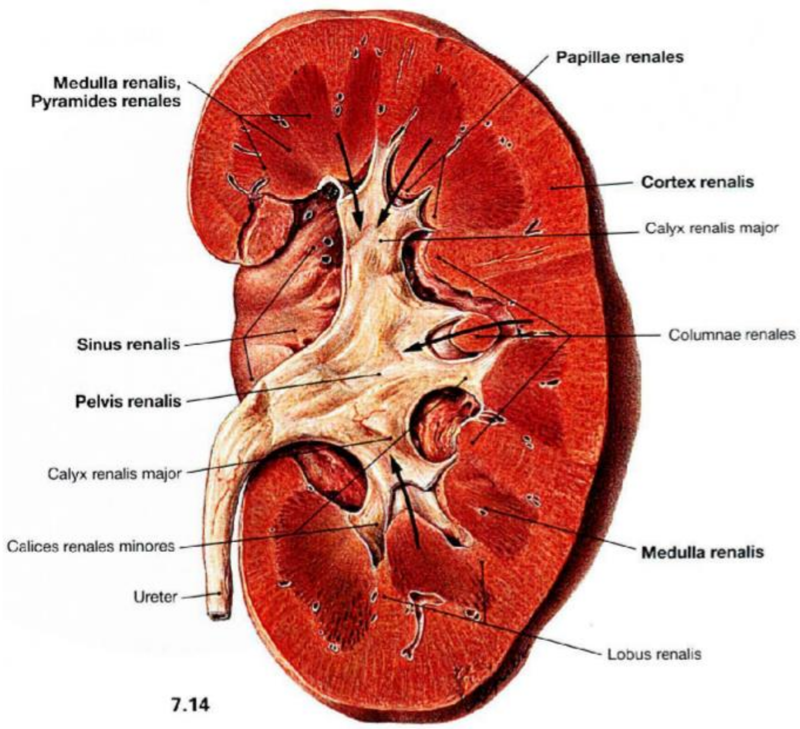


Figure 17 Human left kidney, paramedian section. Source: Studyblue.com

The substance, or parenchyma, of the kidney is divided into two major structures: the outer cortex renale (which is about two centimeters thick) and the inner medulla renalis. Grossly, these structures take the shape of cone-shaped lobus renalis, each containing cortex renale surrounding a portion of medulla called a pyramides renales. These consists of a peripheral pyramidal base and a central renal papilla renalis. In the median plane of the kidney the papillae renales are fused to form what may appear as a large, single, common papilla renalis (crista renalis). Between the pyramides renales are projections of cortex called colomnae renalis. Nephrons, the urine-producing functional structures of the kidney, span the cortex and medulla. The initial filtering portion of a nephron is the corpusculum renis which is located in the cortex. They can be seen as pinpoint circumscribed vascular spaces. A corpusculum renis consists of a coil of blood capillaries, the glomerulus, and a surrounding capsule, into which the primary urine – an ultrafiltrate of the blood plasma – passes. It is into the corpusculum renis of the nephron that the primary urine (about 150 liters daily) is filtered, and it is within its tubular system that the resorption of fluid, including glucose and electrolytes from the primary urine, takes place. In the opposite direction waste products, in particular, urea, and also certain drugs, are excreted. A connecting tubulus joins the nephron to a collecting tubulus. Several collecting tubules join like the branches of a tree, to form a straight collecting tubulus that unites with other collecting tubules to form a ductus papillaris. Within the collecting tubules, owing to an osmotic pressure difference, and under the influence of the antidiuretic hormone, a further resorption of water is realized from the filtrate. The secondary urine is produced this way (about 1.5 liter daily) (Ref. 1,23,24).

The tip, or papilla, of each pyramid drains urine into a calices renales minoris; which drains into calices renales majoris, which drains into the pelvis renalis. This becomes the ureter. At the hilum, the ureter and v. renalis exit the kidney and the a. renalis enters. Hilar fat and lymphatic tissue with lymph nodes surrounds these structures. The hilar fat is contiguous with a fat-filled cavity called the sinus renalis. The sinus renalis collectively contains the pelvis renalis and calices and separates these structures from the medulla renalis tissue (Ref. 1,23,24).

The lymph from the kidney drains into the lumbar aortic lymph nodes (lnn. lumbales aortici). Autonomic innervation of the kidney is by sympathetic and parasympathetic nerve fibers that proceed chiefly from the plexus aorticus abdominalis or plexus coeliacus (Ref. 1,23,24).

The ureter runs between the renal pelvis and the urinary bladder. It lies retroperitoneally, adjacent to the sublumbar muscles. Each kidney excretes urine into a ureter which empties into the bladder (Ref. 1,23,24).

The vascular system of the kidney has complicated topographical relations to the urine conducting, looplike tubulus renalis. The kidneys receive blood from the paired arteriae (aa.) renalis, and drain into the paired venae (vv.) renalis. The a. renalis divides into aa. interlobularis, which run between the lobes and are continued by the aa. arcuata. The aa. interlobularis give off the afferent glomerular arterioles, which at the vascular pole of each corposculum are continued by a glomerulus. The efferent glomerular arteriole originates from the vascular pole of the glomerulus and is continued by a dense capillary net in the area of the tubulus. The first capillary net (glomerulus) filters the primary urine. From the second capillary network (tubulus net) the venous drainage of the kidney commences (Ref. 1,23,24).

1.6.2. Adrenal glands

The adrenal glands are endocrine glands that lie craniomedially to the kidney. Their cortical part has a yellowish tinge owing to the content of stored lipid substances utilized in the synthesis of steroid hormones. The medulla produces the hormones epinephrine and norepinephrine. Both adrenals lie retroperitoneally and are incompletely divided ventrally into cranial and caudal parts by the v. abdominalis cranialis that lies in a deep transverse groove of the gland. The right adrenal is the more cranially situated and lies next to the caudal vena cava; the left adrenal abuts on the abdominal aorta. Their blood supply is multiple and is from the suprarenal arteries and veins that originate from the aorta or the caudal vena cava, respectively (Ref. 1,23).

1.6.3. Intestines

The digestion and absorption of nutrients take place within the small intestine. Associated with this function, the internal intestinal surface is considerably increased by circular folds, intestinal villi, crypts of the mucous membrane and microvilli of its enterocytes. The small intestine consists of duodenum, jejunum and ileum and extends from the pylorus to the opening of the ileum into the large intestine. It is about three and one-half times the length of the body (Ref. 1,23).

The duodenum is shaped like a hook and surrounds the pancreas. It begins with the cranial part, which ascends to the right and dorsal as far as the porta of the liver and after this continues at the flexura duodeni cranialis as the descending part. The descending part bears at its beginning internally the papilla duodenalis major. Three fingerbreadths farther caudal the papilla duodenalis minor is located. The descending part continues at the flexura caudalis as the transverse part. The latter lies caudal to the a. mesenterica cranialis and, after a transverse course to the left across the midline, continues as the ascending part. At the flexura duodenojejunalis the ascending part is continued as jejunum (Ref. 1,23).

The jejunum is by far the longest portion of the small intestine and is suspended by a long mesojejunum that permits a wide distribution of the jejunal loops between the stomach and the pelvic inlet. The short ileum begins at the indistinct free end of the ileocecal fold. The ileum ends with a fairly straight course at the ostium ileale and surrounding m. sphincter ileale at the junction with the colon ascendens (Ref. 1,23).

It is in the large intestine that the reabsorption of water, and dissolved electrolytes together with the digestive juices, takes place. On the lumenal surface of the large intestine, villi are absent and the crypts of the large intestine are particularly deep. The mucosa bears longitudinal folds. The canine large intestine is short and simply formed in comparison to this part of the gut in other domestic animals. The large intestine is composed of caecum, colon, rectum and anal canal (Ref. 1,23).

The cecum is coiled like a corkscrew and consists of an apex, and a body that abuts on the colon ascendens. The caecum lies on the right side within the concavity of the C-shaped duodenum. The caecum can be considered as a diverticulum of the colon. Both parts of the large intestine are in communication at the ostium caecocolicum, which is found beside the ostium ileale that also opens into the colon ascendens (Ref. 1,23).

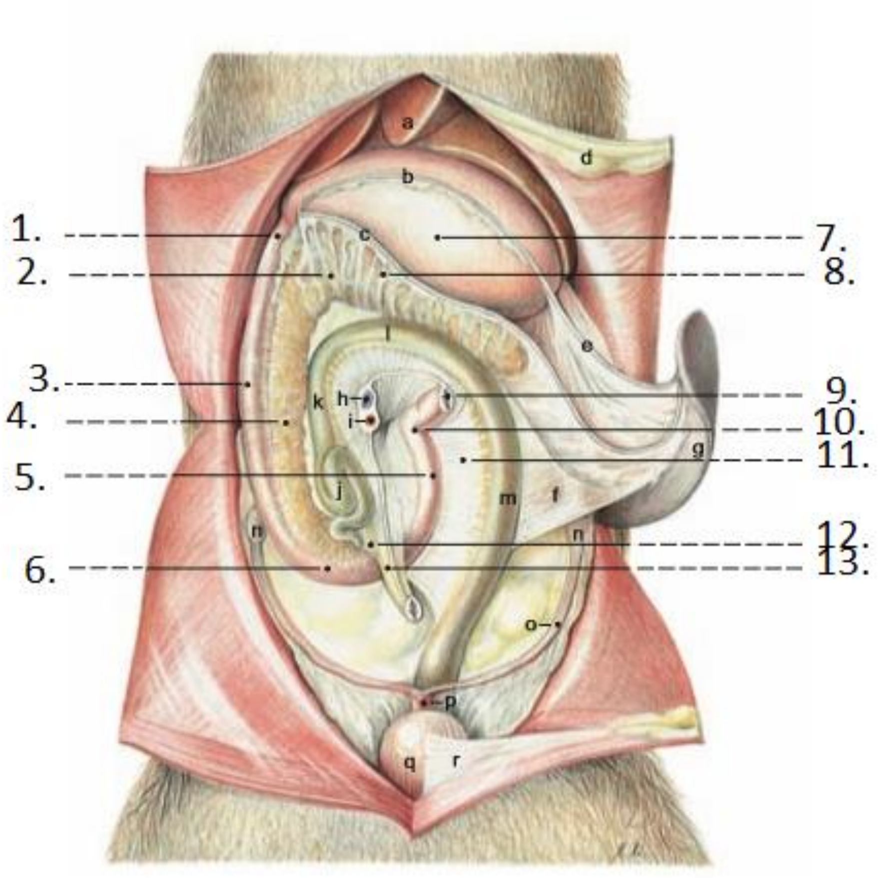
The colon is shaped like a hook and commences on the right hand side from the ostium caecocolicum with the short colon ascendens, which ascends to the level of the a. mesenterica cranialis. At the flexura colica dextra, cranial to the a. mesenterica cranialis, the colon transversus continues its course, which again opens into the colon descendens at the flexura colica sinistra (Ref. 1,23).

The rectum commences at the pelvic inlet, about at the T-shaped termination of the a. mesenterica caudalis into the a. colica sinistra and a. cranial rectalis cranialis. Just cranial to its continuation as anal canal it is dilated as the ampulla rectalis. Anal closure is chiefly brought about by internal and external anal sphincter muscles (Ref. 1,23). See figure 18 for an illustration of the intestines.

The arteries of the intestines originate from the a. coeliaca, a. mesenterica cranialis and caudalis, which are ventral branches of the aorta abdominalis. The a. coeliaca divides into three main branches: The a. gastrica sinistra, the a. lienalis and the a. gastroepiploica sinistra. The a. hepatica passes to the porta hepatis and continues as the a. gastroduodenalis. The latter bifurcates into the a. gastroepiploica dextra and the a. pancreaticoduodenalis cranialis. The a. pancreaticoduodenalis cranialis anastomoses on the duodenum with a branch of the a. mesenterica cranialis. The a. mesenterica cranialis releases the a. ileocolica, the often double a. pancreaticoduodenalis caudalis, a. jejunale, and ends as the a. ileale. The a. ileocolica branches into the a. colica media for the colon transversus, the a. colica dextra and the ramus colicus for the colon ascendens and divides into the a. caecalis and the ramus mesenterica ileale. The a. caecalis is continued onto the ileum as the ramus antimesenterica ileale. The a. mesenterica caudalis gives off the a. rectalis cranialis to the rectum and the a. colica sinistra, which anastomoses on the colon descendens with the a. colica media (Ref. 1,23).

The v. porta is formed by three main branches. These are 1. the v. gastroduodenalis which at the level of the stomach opens into the v. porta from the right, and 2. the v. splenica, which passes from the left and opens into the v. porta about 4 cm caudal to the v. gastroduodenalis. By reason of its receiving the left v. gastrica, the v. splenica is also designated the v. gastrolienalis. 3. The strongest contribution to the v. porta is by the v.

mesenterica communis, which is formed by the confluence of the v. mesenterica cranialis and caudalis (Ref. 1,23).



Legend:

1. *cranial part of duodenum*
2. *body of pancreas*
3. *duodenum pars descendens*
4. *right lobe of pancreas*
5. *duodenum pars ascendens*
6. *duodenum pars transversus*
7. *stomach*
8. *left lobe of pancreas*
9. *jejunum*
10. *flexura duodenojejunalis*
11. *duodenocolic fold*
12. *ileocaecal fold*
13. *ileum*

a. *liver*
omentum majus:
b. *superfiscial wall (section)*
c. *deep wall (section)*
d. *lig. falciforme en lig. teres hepatis*
e. *lig. gastrosplenicum*
f. *velum omentale*
g. *spleen*
h. *v. mesenterica communis*
i. *a. mesenterica cranialis*
j. *caecum*
k. *colon ascendens*
l. *colon transversum*
m. *colon descendens*
n. *ovary*
o. *uterine horn*
p. *body of uterus*
q. *urinary bladder*
r. *lig. mediale of bladder*

Figure 18 The intestines, stomach and pancreas of the dog. Ventral view. Source: Budras, McCarthy, Fricke and Richter (2007) p. 55

1.6.4. female genital organs

During pregnancy, the uterus is the place for development of the fertilized germ cell. The vagina and vestibule are the organs that follow caudal to the uterus. The ovary, the female gonad, produces the germ cells and functions in addition as an endocrine gland. The ovary is bilaterally flattened. Its size is dependent on the stage of the sexual cycle and is about 15 x 10 x 6 mm (in a medium sized dog). The ovary is concealed within the ovarian bursa, which is a space whose walls consist of the mesovarium and mesosalpinx. It is accessible through a medial slit, the ostium of the ovarian bursa. The ovaries lie suspended by the mesovarium, caudal to the kidneys, at the level of the 4th or 5th lumbar vertebra. Cortical and medullary parts can be distinguished. The cortex of the ovary contains ovarian follicles and, depending on the phase of the sexual cycle, also corpora lutea. The corpora lutea are formed from the wall of the follicle following ovulation. The medulla contains a dense network of blood and lymph vessels as well as autonomic nerves (chiefly sympathetic) (Ref. 1,23).

After ovulation, the uterine tube (salpinx) transports the ovum to the uterus and, moreover, functions as the site of conception. It is 5 – 10 cm long and only a few mm thick. The end-part of the salpinx, is called the isthmus. The infundibulum with the centrally located abdominal ostium of the salpinx and the surrounding tubal fimbriae are located lateral to the ovary at the edge of the bursal ostium (Ref. 1,23).

According to comparative anatomical classification, the canine uterus (metra) is bicornuate. In the sexually mature, non-pregnant, mediumsized bitch, the uterine horns are about 12 cm long and, after their union, are continued caudally into the uterine body. The body of the uterus is only 2 – 3 cm long. Besides horns and body, the cervix uteri is that part of the uterus that has the narrowest lumen and the firmest muscular coat. The uterine cervix is about 1 cm long and projects with its vaginal portion into the vagina. The wall of the uterus consists of three-layers altogether: endo-, myo-, and perimetrium (Ref. 1,23).

The vagina has longitudinal and transverse mucosal folds. It is compressed dorsoventrally by neighbouring organs (dorsally, the rectum; ventrally, the feminine urethra) and has dorsal and ventral walls and a narrow transverse lumen. The length of the vagina is about 12 cm, extending cranially to the vaginal fornix, which surrounds the vaginal portion of the cervix ventrally and laterally, and caudally to the vaginal ostium. Ventrally, at the vaginal ostium, the external urethral ostium is found. Like the uterus, the vaginal wall is also three-layered (Ref. 1,23).

The vestibule of the vagina extends from the vaginal ostium to the vulvar cleft. The vestibule is at first horizontally positioned and, after this, continues caudally by a ventral archlike portion that becomes more prominent with increasing age. Smooth muscle of the vestibular wall is sparse. The accessory genital glands (minor vestibular glands) secrete a viscous fluid (Ref. 1,23).

The external genital organs are the female vulva (pudendum femininum), the clitoris, and the feminine urethra (Ref. 1,23).

The blood supply of the vulva, including the vestibule, is provided by branches of the vena and a. pudenda interna, that also give off the vena and a. vaginalis that, in turn, dispatch the vena and a. uterina. The uterina vessels run in the mesometrium, form arcades, and anastomose at the tip of the uterine horn with the uterine branch of the a. en v. ovaria. The latter vascularize the ovary and also participate in the blood supply of the salpinx. The venous ramus uterina is especially strong, because it is the main drainage of the uterus.

The lymph drainage of the ovary, uterine tube, and cranial tip of the uterine horn is to the aortic lumbar lymph nodes (lnn. lumbales aortici); the lymph drainage of the other parts of the uterus and the vagina including the vulva is to the medial iliac and sacral lymph nodes (Ref. 1,23).

The autonomic nerve supply of the ovary, including the uterine tube, is by the plexus aortica abdominalis with the plexus ovaria, intermesenterica, and mesenterica caudalis. Uterus and vagina are supplied by the plexus pelvicus. The external genital organs are supplied with autonomic, motor, and sensory fibers by the n. pudenda (Ref. 1,23).

The feminine urethra measures only a few centimeters and is considerably shorter than the male urethra. It begins at the neck of the urinary bladder with the ostium urethrae internum and ends ventrally at the ostium vaginalis between vagina and vestibule with the ostium urethrae externum that opens into the tuberculum urethrale. The urethra is located between the pelvic floor and the vagina. The initial part is similar to the neck of the urinary bladder and is structured by external longitudinal and internal circular smooth muscle cell bundles. The caudal part contains in its wall a venous erectile body and the striated m. urethralis that assure the closure of the urethra (Ref. 1,23). See figure 19 for an illustration of the ovary, uterus, and associated structures.

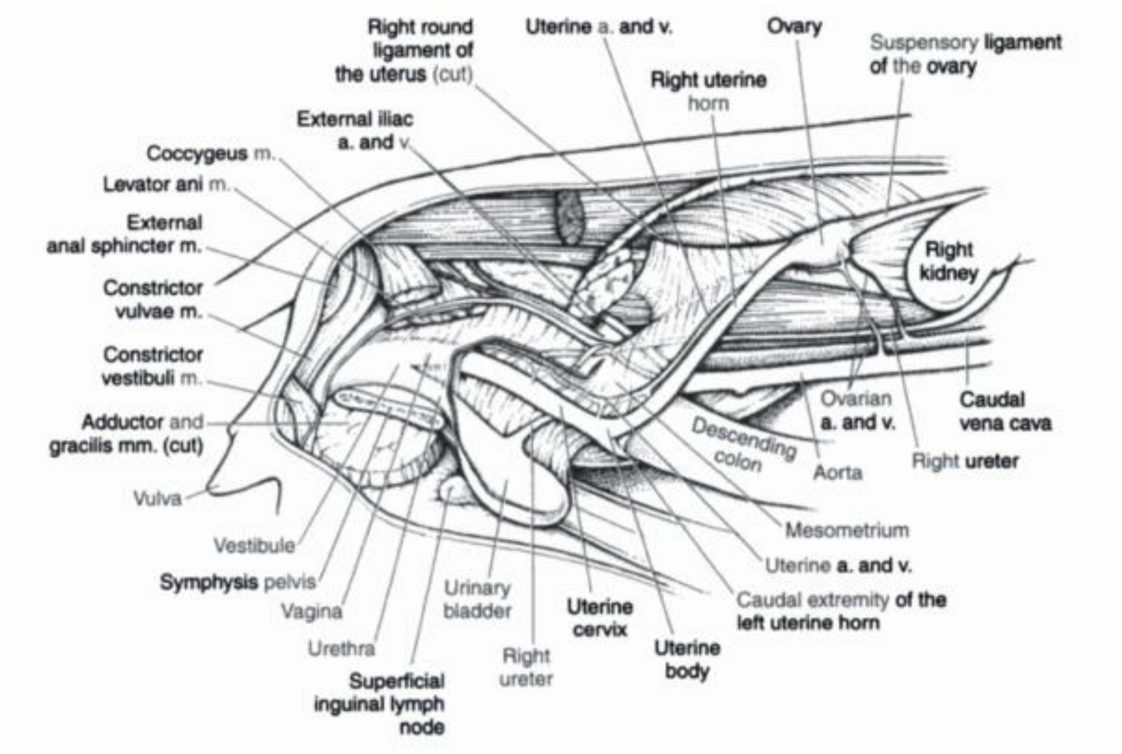


Figure 19 The ovary, uterus, and associated structures (right lateral view) Source: Miller's Anatomy of the Dog, 3e. Philadelphia, WB Saunders, p.534

1.6.5. Male genital organs

The genital organs of the male dog are, like those of the bitch, subdivided into internal and external genital organs. Following the descent of the testis into the scrotum, the internal genital organs are the testes, which are the germ cell forming organs, the organs that conduct the germ cell to the urethra (epididymis and ductus deferentes), and the accessory glands. The testicles lie in the scrotal cavity (Ref. 1,23). See figure 20 for a drawing of the male genital organs.

The epididymis is the germ cell-conducting, germ cell-maturing, and for a limited period of time, a germ cell-storing organ. The epididymis is divided into the thickened head of the epididymis, which is the place where the efferent ductules unite to form the single ductus epididymis, the slender body of the epididymis, and the tail of the epididymis, which is an enlargement at the caudal end of the body. The body and tail of the epididymis contain the strongly coiled ductus epididymis, which has a length of several meters (Ref. 1,23).

The ductus deferentes is the continuation of the ductus epididymis. The first part of the ductus deferentes is in the spermatic cord. The terminal portion of the ductus deferentes reaches the abdominal cavity. Just before its reaching the prostate, the ductus deferentes has a very slight spindle-shaped enlargement in the wall of which are accessory sex glands, the ampullary glands. The continuing narrow terminal opens into the urethra. Its opening is the ostium ejaculatorium (Ref. 1,23).

The prostate is the second accessory sex gland. The function of the prostate is to secrete a slightly alkaline fluid. The prostatic fluid is expelled in the first ejaculate fractions, together with most of the spermatozoa. The spermatozoa expelled in prostatic fluid have better motility, longer survival and better protection of the genetic material. The prostate surrounds the urethra just below the urinary bladder. The prostate also contains some smooth muscles that help expel semen during ejaculation (Ref. 1,23).

The external genital organs are the penis and prepuce, the urethra, and the scrotum.

The penis is formed by two different types of cavernous body. The one type is the hard, paired erectile body, the other part is the spongy, soft, unpaired cavernous body of the urethra. Erection of the penis is brought about by an increase in blood pressure within the vascular spaces of the cavernous tissue. This is the result of an increased inflow of blood that is supported by a dilatation of the penile arteries and a decrease in the drainage of the penile veins (Ref. 1,23).

The masculine urethra commences at the urinary bladder and ends at the tip of the glans of the penis. At the ostium ejaculatorium, the path of the urine and that of the semen join (Ref. 1, 23).

The blood supply of the testicle, including the epididymis, is provided by the a. testicularis, which originates from the abdominal aorta about at the level of the third lumbar vertebra. The ductus deferentes, urethra and prostate are supplied by branches of the a. pudenda interna. The v. testicularis originates on the right side from the caudal vena cava, on the left from the left v. renalis and forms the plexus pampiniformis dorsal to the head of the epididymis. The branches of the venous plexus enlace the a. testicularis. The veins of the ductus deferentes, urethra and prostate drain the blood from the ductus deferentes, urethra and prostate to the v. pudenda interna (Ref. 1, 23).

The innervation of the testicle and epididymis is by the plexus testicularis and is within the spermatic cord. It has connections with the plexus aortica abdominalis and plexus mesenterica caudalis. The prostate and deferent plexuses supply the corresponding organs (prostate and ductus deferentes). They branch from the plexus pelvicus and contain sympathetic, parasympathetic and sensory fibers. The n. pudenda supplies the dorsal nerve of the penis, which conveys sensory, sympathetic and parasympathetic fibers (Ref. 1, 23).

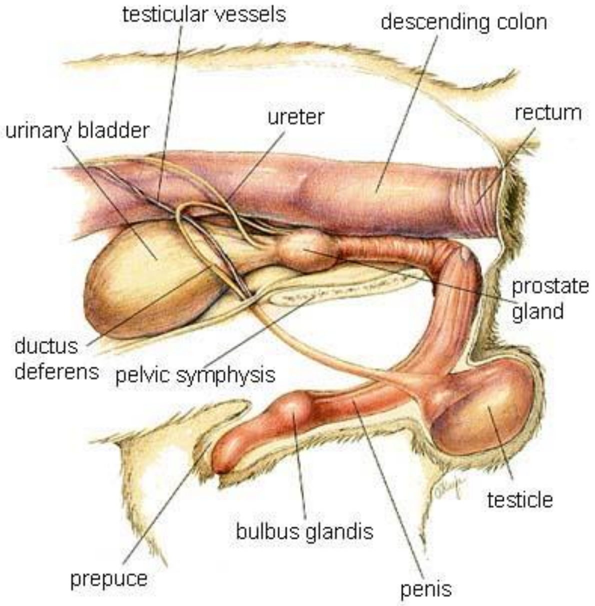


Figure 20 The male genital organs and associated structures (left lateral view) Source: Studyblue.com

1.6.6. Urinary bladder

The bladder lies clothed by the peritoneum. The urinary bladder has a cranial apex (vertex), a central body (corpus vesicae) and a caudal neck (cervix vesicae). Dorsally, at the neck of the bladder, the ureters, converging, traverse the wall obliquely. They lie just deep to the mucosa and create internally a moderate swelling, the columnae uretericae, that can be traced caudally to the opening of each ureter (ostium ureteris) into the bladder. Ureteral folds continue caudally from the openings, uniting at the transition of the urinary bladder to the urethra, the ostium urethrae internum (Ref. 1,23).

The blood supply of the urinary bladder is mainly from the a. vesicalis caudalis, which runs from the pelvic cavity to the urinary bladder. The total venous drainage passes to the v. vesicalis caudalis. The lymph vessels pass to the sacral lymph nodes. The autonomic innervation is from the plexus pelvicus. Within the wall of the urinary bladder intramural nerve plexuses containing ganglion cells regulate the contraction of the muscular wall (Ref. 1,23). See figures 19 and 20 for illustrations of the bladder. In the same illustrations the female and male genital organs are shown.

1.6.7. Liver

The functions of the liver are manifold and correlate with the remarkable size of the organ, which is about 3.3 % of the body weight. Besides metabolic functions in the metabolism of carbohydrate, protein and fat, the liver has significant functions in inactivating hormones and detoxifying foreign. Prenatally, this largest of the internal organs has an even greater share of the total body weight; because in the foetus additionally it has the important function of blood cell formation. The position of the liver is predominantly intrathoracic. The lobus hepatis dexter lateralis of the liver and the processus caudatus of the lobus caudatus border on the right kidney at the level of the last rib. The lateral border of the liver runs roughly parallel to the costal arch. Only the ventral portion of the liver is extrathoracic, resting on the lig. falciforme with its abundant fat tissue. The surface of the liver with its smooth convex diaphragmatic surface is in contact with the diaphragm and matches the form of the diaphragmatic cupola. Its concave visceral surface is directed to the abdominal organs. Stomach, duodenum, colon and the right kidney bring about impressions on the firm-elastic surface of the organ. Of the borders of the liver, the dorsal border is rounded and bears the oesophageal impression; whereas, the other margins of the healthy organ are sharp (Ref. 1,23).

The lobes of the liver of the dog are well demarcated by deep fissurae interlobares. The resulting distinct lobation is supposed to correlate with the clearly expressed dynamics of the vertebral column. The liver is subdivided by two lines that extend from its dorsal to its ventral border. The left line runs between the dorsally located oesophagus and the ventrally situated lig. teres of the liver, which, in the mature dog, is usually absent. The right line connects the caudal vena cava, which is dorsal and the ventrally located gall bladder. Between the two lines, the lobus quadratus is ventral to the porta hepatis and the lobus caudatus is dorsal. The lobus caudatus consists of the large processus caudatus, which is connected to the right kidney by the lig. hepatorenale, and the small, left-projecting processus papillaris, which is ventral to the omentum minus. Lateral to the connecting lines are right and left lobes, which are separated by intralobar fissures into a lobus hepatis dexter medialis and a lobus hepatis dexter lateralis, and a lobus hepatis sinister medialis and hepatis sinister lateralis. The hepatic lobules have a diameter of 1 – 1.5 mm and a height of 1.5 – 2 mm (Ref. 1,23).

The afferent blood vessels, branches of the vena porta and a. hepatica, surround the periphery of the lobules and mark the corner points of a hexagonal, classical hepatic lobule. The central vein is central within the liver lobule. It represents the first part of the hepatic venous system, which drains blood from the liver (Ref. 1,23).

The ligaments of the liver fix the organ predominantly to the diaphragm. The lig. triangulare dextrum and lig. triangulare sinistra fix the lobus hepatis dextra and lobus hepatis sinistra. The lig. coronarium that continues medially from them fixes the lobus hepatis sinister medialis and lobus hepatis dexter lateralis. The lig. hepatorenale runs between the processus caudatus and the right kidney. The lig. falciforme is the distal portion of the ventral mesogastrium. In the foetus the v. umbilicalis of the liver runs in the free border of the lig. falciforme from the umbilicus to the liver. In the mature dog, the v. umbilicalis is lost, the lig. teres of the liver does not persist, and the lig. falciforme is present only as a short fold ventral to the caudal vena cava as it departs the liver cranially and a much larger fat-filled fold caudally at the level of the umbilicus. The Area nuda of the liver is a zone of adhesion where the liver is joined to the diaphragm by connective tissue; this area is free of peritoneum and lies to the right and left of the caudal vena cava as it passes through the liver (Ref. 1,23).

The omentum minus is subdivided into the lig. hepatoduodenale and lig. hepatogastricum, which originate from the named origins and converge to the porta of the liver (porta hepatis). The ductus choledochus runs in the free border of the lig. hepatoduodenale and, beside it, are the v. porta and a. hepatica (Ref. 1,23).

The following structures pass to and from the liver at the porta hepatis: v. porta (functional blood vessel), the a. hepatica (nutrient blood vessel), ductus hepaticus dexter and sinister, vagal and sympathetic branches as well as lymph vessels that pass to the hepatic (portal) lymph nodes. The blood supply of the liver is from two sources: with respect to size, the v. porta with its branches is the main supply, providing venous blood rich in nutrients. The small calibered a. hepatica with its branches conveys oxygenated blood to the liver. After entering the liver, the v. porta divides into right and left branches that primarily supply the liver. The a. hepatica divides similar to the portal vein. The vv. hepatica open into the embedded vena cava caudalis at the dorsal border of the liver (Ref. 1,23).

The v. porta of the liver collects blood from organs of the gastrointestinal tract and the spleen. The lymph drainage of the liver is to the hepatic (portal) lymph nodes, which are located near the porta. The sympathetic and parasympathetic nerve supply is by the plexus hepaticus, the constituents of which enter the liver at the porta together with the a. hepatica (Ref. 1,23).

Outside the liver, at the opening of the last ductus hepaticus, the ductus cysticus of the gall bladder, is continued by the ductus choledochus, which has a sphincter muscle (m. sphincter ductus choledochus). The ductus choledochus opens on the papilla duodenalis majoris (Ref. 1,23).

The gall bladder stores the bile insofar as it has not flowed directly into the duodenum. In the gall bladder, the golden coloured bile is first dehydrated. This makes the bile thicker and changes its colour to dark green. The gall bladder lies between the lobus medialis dextra of the liver and the lobus quadratus. In the adult dog the fundus of the gall bladder extends to the diaphragm. The body of the gall bladder is continued by a constricted part, the neck of the gall bladder. The latter continues as the ductus cysticus. The bile may traverse the ductus cysticus in various directions: during digestion, into the duodenum; in intervals between digestion, from the liver for storage in the gall bladder (Ref. 1,23). See figure 21 on the next page for an illustration of the liver and gall bladder.

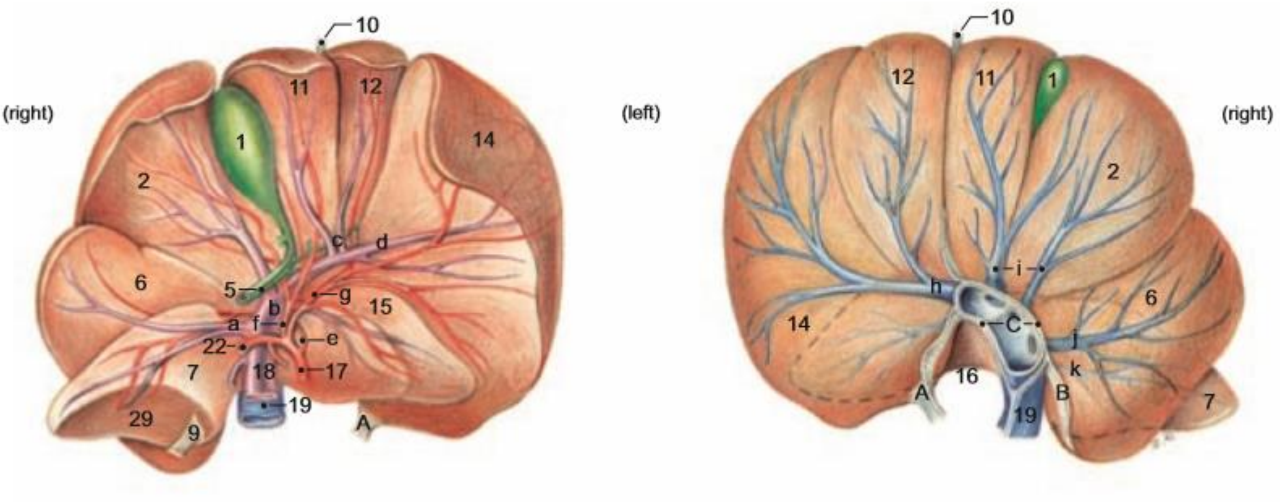


Figure 21 The liver; visceral surface (left) and diaphragmatic surface (right). Source: Budras, McCarthy, Fricke and Richter (2007) p. 59

Legend:

1. gall bladder
2. lobus hepatis dexter medialis
6. lobus hepatis dexter lateralis
7. processus caudatus of lobus caudatus
9. lig. hepatorenale
10. lig. falciforme and lig. teres hepatis
11. lobus quadratus
12. lobus hepatis sinister medialis
14. lobus hepatis sinister lateralis
15. processus pappilaris of lobus caudatus
16. oesophageal impression
17. a. hepatica
18. v. porta
19. v. cava caudalis
A.   Lig. triangulare sinistrum
B.   Lig. triangulare dextrum
C.   Lig. coronare
a-d. v. porta
e-g. a. hepatica
h-k. vv. hepatica

2. Osteopathic vision

2.1. What is osteopathy?

Andrew Taylor Still, MD, DO (1828 –1917) was the founder of osteopathy and osteopathic medicine. He was also a physician and surgeon, author, inventor and Kansas territorial and state legislator. He was one of the founders of Baker University, the oldest four-year college in the state of Kansas, and was the founder of the American School of Osteopathy (now A.T. Still University), the world's first osteopathic medical school, in Kirksville, Missouri (Ref. 25,26).

Still defined osteopathy as:

" that science which consists of such exact, exhaustive, and verifiable knowledge of the structure and function of the human mechanism, anatomical, physiological and psychological, including the chemistry and physics of its known elements, as has made discoverable certain organic laws and remedial resources, within the body itself, by which nature under the scientific treatment peculiar to osteopathic practice, apart from all ordinary methods of extraneous, artificial, or medicinal stimulation, and in harmonious accord with its own mechanical principles, molecular activities, and metabolic processes, may recover from displacements, disorganizations, derangements, and consequent disease, and regained its normal equilibrium of form and function in health and strength. "(Ref. 25,26).

Figure 22 Dr. Still, founder of osteopathy. Source: Wikipedia

For this thesis, it is of importance that the definition of osteopathy is kept in mind when a dog is treated for a hip joint problem. The cause can be searched in the whole body, not only in the hip joint or hind paw.

Osteopathy in humans distinguishes three systems: the parietal, the visceral and the craniosacral system. Those three systems interact with each other (Ref. 25,26). However, not much evidence can be found of the craniosacral system of the dog, so in this thesis the focus is on the other two systems.

2.2. Osteopathic lesion

An osteopathic lesion means a lack of mobility, or no mobility, between the facet joints of the spine, with segmental appearances as a result. A restriction is a pre stadium of an osteopathic lesion, so the joint is almost blocked (Ref. 27).

It is assumed that the reader of this thesis knows how an osteopathic lesion can cause pain. For a detailed description, see reference 27, 28 and 29. The treatment of an osteopathic lesion will not be discussed either. For information about for example a rebound technique or a jones technique, there will be referred to reference 30, 31 and 32.

An osteopathic lesion which is present for a longer time ensures that all information leaving the segment is disturbed information. Eventually, this leads to hypertonia (abnormally increased tone) of the autochthone paravertebral muscles around the segment, but also via the ramus ventralis, hypertonia of the muscles at the ventral side of the body, corresponding to the particular segment. In the segments where ribs are present, an osteopathic lesion can cause hypersensitivity of the periosteum of the ribs. Other reactions in the particular segment are piloerection (erection of the hair of the skin); hyperesthesia of the skin; a disturbance in the sweat secretion; reduced circulation of blood to the viscera innervated by this segment; and vasoconstriction. This leads to a reduced circulation of blood to various tissues. The result of this vasoconstriction is worse discharge of wastes, and acidification. The tissues become hyper tone and trigger points arise (Ref. 27).

An osteopathic lesion can arise because of various causes. For example, it can be a result of a trauma, or it can be a secondary problem resulting from an underlying primary problem elsewhere in the organism. In some cases, a visceral problem is the course of an osteopathic lesion. If a visceral problem is the cause of an osteopathic lesion, this problem must be solved as well. Otherwise the osteopathic lesion will return quickly. If an osteopathic lesion is longer existing, it will influence the viscera and other structures which are related to this segment. In most cases an osteopathic lesion will become a group lesion eventually (Ref. 27,28,29).

For the hip joint, this means the thoracic-lumbar zone is the most interesting zone. An osteopathic lesion in this region, will influence the orthosympathetic and motoric information to the hind paw (Ref. 31,32). In the following chapters, this will be explained in more detail; in the chapters about viscera (2.5), the influence of visceral problems on the hip joint, and their relation with osteopathic lesions in the spine will be explained. In chapter 2.6, the influence of hyper and hypo tone muscles (which can be caused by osteopathic lesions) will be explained.

2.3. Arterial rule

The life and the functioning of each individual cell of the body can only be ensured by an undisturbed blood flow. "The rule of the artery is supreme" (A.T. Still). If the blood supply is restricted to muscle and tissue cells, the performance of muscles and the elasticity of the tissue are reduced. Not only the transport of nutrients, but also the removal of metabolic products is impaired. Reduced removal of the waste materials leads to over-acidification of the tissue and inflammatory processes can develop. Trophic disorders of the skin, impaired growth of nails and hairs, inflammations of the skin and wounds, poor wound healing, muscular spasm, acidification and hardening of muscles, atrophy, degeneration of bones, compression syndromes of fasciae, hormonal disturbances, indigestion, and paralysis are some problems which can develop when the arterial supply is insufficient. Edema, swelling, cysts, and problems related to over-use of anastomoses and the lymphatic system are examples of problems that can occur when the venous drainage is not sufficient (Ref.33).

Homeostasis is the process by which the body makes continual adjustments to keep itself in a stable condition and function to the best of its ability. This process will be harder when the blood flow is impaired.

The blood flow cannot be influenced directly, but it can be influenced via the orthosympathetic control of the blood vessels. Activation of the orthosympathetic system causes vasoconstriction. The vasodilatation, however, is less attributed to the parasympathetic system, but to the reduced activity of the orthosympathetic system (Ref. 33).

The cause of an insufficient blood supply and venous drainage can be an disturbance of the orthosympathetic efferent information, as seen above. Of course this is not the only possibility. Parasites and a wrong diet can affect the blood supply to the abdominal organs in a negative way. See chapter 2.7 for more information about these external factors.

Hyper tone muscles and fascia, and osteopathic lesions can affect the blood supply too (Ref. 18,33).

For good functioning of the hip joint, sufficient blood supply is necessary. Insufficient blood supply of the hip region can result for example in degeneration of the femur or acetabulum, changes in synovial fluid, acidification and hardening of muscles around the hip joint, or inflammatory processes in this region (Ref. 33).

2.4. Fascia

In the anatomy chapters the fascia surrounding the canine hip are described. In this chapter, the osteopathic vision about fascia will be described.

2.4.1. Fascia in general

Fascia is a specialized system of the body that has an appearance similar to a spider's web. Fascia is very densely woven, covering and interpenetrating every muscle, bone, nerve, artery and vein, as well as, all of our internal organs including the heart, lungs, brain and spinal cord. The most interesting aspect of the fascial system is that it is not just a system of separate coverings. It is actually one continuous structure that exists from head to toe without interruption. This explains how each part of the entire body is connected to every other part by the fascia (Ref. 18).

Fascia plays an important role in the support and function of the body, since it surrounds and attaches to all structures. Hemodynamic and biochemical processes are made possible by fascia. Fascia can be seen as a medium that allows for intercellular communication. They guarantee blood flow, because blood vessels are surrounded by fascial sleeves. Besides, fascia plays a role in defence against pathogenic agents and infections, and tissue repair (Ref. 18,34).

In the normal healthy state, the fascia is relaxed and wavy in configuration. It has the ability to stretch and move without restriction. An important feature of fascia, is that it can contract in a smooth-muscle like manner by the activity of myofibroblasts. When an animal experiences physical trauma, emotional trauma, scarring, or inflammation, however, the fascia can lose its pliability. It can become tight, restricted, and a source of tension to the rest of the body. The changes that a trauma causes in the fascial system influences comfort and function of the body. Fascial restrictions can exert excessive pressure causing all kinds of symptoms producing pain, headaches or restriction of motion. Fascial restrictions affect flexibility and stability, and are a determining factor in the ability to withstand stress and perform daily activities. When tension in fascial structures persist, they can affect the whole body (Ref. 18,34).

Inflamed serous sheets have a tendency to stick together, and in the course of time these adhesions may become organized and permanent. Adhesion between organs that are normally free to move over each other is a possible and undesirable cause for infection or trauma of the peritoneum. Clearly, any attachment that limits mobility may interfere with normal function. However, it must be noted that adhesion of against each other resting serosal surfaces (with the obliteration of the intervening space) is commonplace in development and explains the definitive position and arrangement of many organs and mesenteries (Ref.18).

2.4.2. Fascial structures of the hind limb

In the anatomical chapters the various fasciae are described. In this chapter, an introduction about fascial structures of the hind limb and their influence on the hip joint is made. This will be explained further in the following chapters.

The fascia iliaca wraps the psoas muscles. Thus, it is in contact with the kidneys, ureter, caecum, colon ascendens and colon descendens. In addition, the fascia iliaca embeds the lumbar plexus. It stabilizes and assures the contention of the sublumbar muscles in keeping them against the vertebrae and the ala of the ilium, thus allowing them to follow the iliolumbar curve (Ref. 18). Therefore, adhesions in this fascia can affect the psoas muscles, the kidneys, caecum, ureter, colon ascendens and colon descendens. In which way these organs can affect the hip joint will be shown in chapter 2.5. In which way the psoas muscles can affect the hip joint, will be shown in chapter 2.6.1.

The fascia iliaca proceeds into the fascia femoralis from the trochanter minor, and laterally it proceeds into the fascia transversalis. The latter fascia can be of importance in the healing after castration. At the inside, the fascia transversalis is in contact with the parietal layer of the peritoneum (Ref. 18). So, adhesions of the peritoneum can theoretically proceed to the fascia transversalis and vice versa.

The fascia thoracolumbalis has a fascial connection with the lig. supraspinale, lig. interspinale, lig. flavum, and the capsula articularis of the spine. So a superficial traction or tension proceeds into the depth at every vertebral segment (Ref. 18). A change in range of motion of the spine, affects the hip joint biomechanically. When an osteopathic lesion occurs in the thoracic or lumbar region (in the region where the cornu laterale is present), the underlying organs can be affected as well. Some of these organs can affect the hip joint too (see chapter 2.5). The fascia thoracolumbalis is also a link between the front side and the hind limb of the animal.

2.4.3. Peritoneum

With reference to the anatomical chapters above, the peritoneum covers the internal surface of the abdomen, and covers the abdominal and pelvic organs. Adhesion between organs that are normally free to move over each other is a possible and undesirable sequel to infection or trauma of the peritoneum, but the other way around is possible too. Adhesions of the peroneal folds always cause a loss of mobility and motility for the abdominal organs and intestines. The vascularisation of the abdominal organs runs through the serous layers of the peritoneum and will thus be reduced by peritoneal tension (Ref. 18). What happens when the blood flow is reduced, is partially seen above in the chapter about the arterial rule. Reduced vascularisation of the peritoneum, can result in a disturbance of the resorption of peritoneal fluid, and thus a disturbance in lubricating of the viscera. When viscera can’t slip freely over each other, or against the abdominal wall, the mobility/ motility will become affected. Reduced vascularisation increases the chance of bacterial growth, and inflammation (Ref. 18).

In the chapter about viscera, chapter 2.5, the peritoneum will be used too to explain the relationships between the viscera and the canine hip joint. The peritoneum is an important link between the viscera and other structures in the body.

2.5. Visceral relations with the canine hip

All parts of the body are, by nature, designed to move, including the internal organs from the lungs to the bladder. Organ movement has two essential features; motility and mobility. Visceral mobility is the movement of the viscera in response to external forces. Motility is caused by the organ's own intrinsic, active motion (Ref. 31).

Illness, disease and dysfunction can arise when either organ mobility or motility become restricted or impaired. Such restrictions usually affect not only an individual organ and its surrounding tissues, but also other organs, as well as distal muscles, ligaments, joints, nerves and blood vessels. Restriction arise from various factors including surgery, injury and trauma, scar formation, stress, improper diet, breathing and digestive difficulties and so forth. In visceral manipulation gentle manual techniques are used to free restriction and restore normal mobility, motility and function to the internal organs and their surrounding tissues (Ref.31).

The functions of viscera may be disturbed by osteopathic lesions. From the region where the osteopathic lesion appears, disturbed information is continuously sent towards the viscera. This causes a visceral dysfunction. The reverse is also possible. If the disorder begins in the viscera itself, the corresponding region in the vertebrae continuously receives disturbed afferent information, which can lead to an osteopathic lesion (Ref.31).

According to Barrel and Harvey, it is well documented that human emotions have a great impact on how their body functions, and this is greatly due to how receptive organs are to feelings. Different emotions affect different organs. Emotional reactions can translate into simple spasms in the gallbladder to heartburn, vomiting, feeling faint, ulcers, and serious diseases. When the brain receives negative emotions it sends tension to the related organ, the organ then sends tension back to the brain resulting in a vicious cycle. Conversely, a physically damaged or imbalanced organ can stimulate emotional upset. Osteopathic treatment of the viscera can break this cycle, enhance the health of the organ, and restore emotional balance (Ref. 36). This documentation is about human emotions. Whether this can also be stated for animals, isn't clear.

Restrictions in the viscera can affect the canine hip. In which way, will be explained in the following chapters.

2.5.1. Kidneys

The kidneys lie retroperitoneally within the retroperitoneal space. The left kidney lies ventral to the first three lumbar vertebrae and the right kidney a half vertebral length more cranial. In female dogs the right kidney lies a bit more cranial than in male dogs. Both kidneys make contact with many other structures, both dorsally and ventrally (Ref. 12,23) .

The right kidney is more extensively related to the liver than to any other organ. Its cranial third is covered by the processus caudatus of the lobus caudatus of the liver. Here arises an impressio renalis. That explains why the right kidney lies clearly in the intrathoracic space of the celiac, while the left kidney lies nearly extrathoracic. The remaining ventral surface of the right kidney is related to the duodenum descendens, the right lobe of the pancreas, the caecum, and the colon ascendens. The vena cava caudalis is on the medial border of the right kidney (Ref. 12,23).

The left kidney is related ventrally to the colon descendens and the small intestine. The spleen is related to the cranial extremity of the kidney. The medial border is close to the aorta. The ovaries are located near the caudal pole of the kidneys (Ref. 12).

The ureter runs between the renal pelvis and the urinary bladder. It lies retroperitoneally, adjacent to the sublumbar muscles. Each kidney excretes urine into a ureter which drains into the bladder (Ref. 1).

Consequently, as seen above the kidneys lie in contact with a lot of structures (connective tissue, organs and muscles). Through connective tissue, like the peritoneum or fascia iliaca, tensions can be transferred from one structure to another. In an osteopathic vision, dysfunctions in these viscera and muscles (for example the duodenum descendens, colon ascendens and liver) could affect the mobility and motility of the kidneys, especially because a lot of waste products are excreted and filtered in this area. Through connective tissue this can lead to tension around the kidneys. Contradictory, these influence on the kidneys seems to be minimal (Ref. 37).

Adrenal glands can’t cause an osteopathic lesion in the thoracolumbar region. This is because these organs can be exhausted, but they won’t sent any disturbed information back to the thoracolumbar region. The adrenal glands cannot be overloaded (Ref. 37).

The m. psoas minor, m. psoas major and the m. iliacus are in contact with the facies dorsalis of the kidneys (Ref. 15). The kidneys glide in their motility over the psoas muscle group (surrounded by their fascia iliaca) (Ref. 18). In case of an osteopathic lesion in the thoracolumbar zone, the information leaving this segment will be disturbed. In time, this can lead to visceral problems. Another possibility, is an osteopathic lesion resulting in hyper tone psoas muscles. The tension of these muscles can be transferred to the kidneys by fascial structures, which can lead to a disturbed mobility and motility of these organs. The other way around is also possible; when there is a kidney disease, or a disturbed kidney function, this can lead to a hyper tone psoas muscle group too. In this case disturbed afferent information of the kidneys enters the thoracolumbar zone too, which can lead (long-term) to an osteopathic lesion. Nevertheless, in most cases, an osteopathic lesion causes a visceral problem. The other way around is not so common (Ref. 37).

When the m. psoas major, m. psoas minor, or the m. iliacus become hyper tone, this affects the position and movability of the pelvis and hip joint. Apart from that, an osteopathic lesion (and thus less movement in the spine) will affect the movability of the pelvis and hip joint too. This will be explained further in chapter 2.6.

2.5.2. Intestines

Every species has its own forage and nutrition habits. This can be seen in the construction of the digestive system and teeth. Dogs evolved directly from the wolf, and they are carnivores. In this chapter the relationships between the intestines and the hip joint will be given from an osteopathic point of view. In chapter 2.7 nutrition and parasites are discussed, and a link to the intestines and the hip joint will be shown.

Intestines can cause an osteopathic lesion in the thoracolumbar region, when disturbed afferent information enters the thoracolumbar zone for a long period. As indicated above, in the chapter about the kidneys, in most cases an osteopathic lesion causes a visceral problem. The other way around is not so common (Ref. 37). However, when intestines cause an osteopathic lesion in the thoracolumbar region, this could affect the hip joint.

The radix mesenteri ensures fixation of the intestinum tenue through the mesenterium. The radix mesenteri is connected to the ventral side of the thoracolumbar junction. Through this mesenterium runs the a. mesenterica cranialis. This artery is important for vascularisation of the intestines (Ref. 38). Osteopathic lesions can for example influence the vascularisation, by vasoconstriction of this artery.

In dogs, the omentum majus plays an important role in immunity and defence (more in carnivores than in herbivores). The vascularisation of the abdominal organs runs through the serous layers of the peritoneum and will thus be reduced by peritoneal tension (Ref. 18). Peritoneal tension can increase for example by a change in mobility/motility of viscera, changes in tension of other connective tissue which is in contact with the peritoneum, and pathologies. Reduced vascularisation can have a negative effect on the immunity and defence function. Waste products can't be transported away efficiently anymore, and tension around the intestines will increase.

The ascending colon and descending colon are fascial connected to the m. psoas major. With digestive problems, fascial tensions can be passed to the psoas muscles (Ref. 39,40). As said before, hyper tone psoas muscles have an effect on the dogs hip joint. See chapter 2.6.1 for more information about the relation between the psoas muscle group and the hip joint.

In dogs, the ileocecal transition sometimes causes problems. This region is in contact with the kidney, and the right psoas muscle group. When the disturbance in the ileocaecal region is transmitted by connective tissue through the psoas muscles, this can lead to a restriction in movement of the hip joint at the right (Ref. 37).

Worm infections will have a negative influence on functioning of the intestines. In chapter 2.7, worm infections will be discussed in detail.

2.5.3. Female genital organs

There is an important osteopathic difference between female and male genital organs. Male genital organs are internally and externally located, female genital organs are predominantly internally positioned. That's why the female genital organs are more influenced, and have more influence on other organs and structures in the dogs body.

The female reproductive organs lie in contact with viscera that carry or filter waste products. This can have negative effects on the reproductive organs. Below, an osteopathic view on the location of the female reproductive organs will be given, and possible influences and effects will be enumerated.

The ovarium dexter lies close to the right kidney, and thus close to the psoas muscle group. The ovarium sinister lies between the loops of the jejunum and colon descendens. The left v. ovarica drains in the left v. renalis, the right one drains directly in the v. cava caudalis (Ref. 1). In case of a kidney disease, or a disturbed kidney function, the venous blood drainage of the ovarium sinister can be disturbed, and pregnancy is more difficult.

Osteopathic lesions in the area of the plexus aortica abdominalis and plexus mesentericus caudalis, will have negative effects on the blood supply to the female reproductive organs. The other way around, can give an inflammation of the uterus for example, a long-term afferent disturbance on the thoracolumbar transition, resulting in a disruption of these segments. From this area, the psoas muscle group gets his innervation. In the process these muscles can get disturbed efferent information, and can become hyper tone (Ref. 37).

The lig. latum not only provides for the suspension of the female genitalia, but also for the circulation and innervation of the reproductive organs. Medial the lig. latum inserts on the dorsolateral side of the uterus. The lateral insertion of the dorsal abdominal wall is located at the level of the lower pole of the kidney. The lig. latum is covered on both sides by peritoneal sheets. Because the peritoneum comprises the lig. latum, the peritoneum can influence the blood circulation of the lig. latum (Ref. 1,41).

The dorsal side of the corpus uteri is in contact with the colon descendens and the rectum, the ventral side with the bladder. The uterus also has a relation with the peritoneum. Peritoneal blades provide for a direct contact between the uterus, colon descendens, and rectum at the upper side and uterus and bladder on the underside. Through his association with many different organs the peritoneum has many relations with these viscera and also affects their performance. In this way, fascial tensions can be transferred to the sub-lumbar region, and hence also to the psoas muscles (Ref. 1,41).

In the genital organs, blood flow is important. Hormones will be transferred through blood to the reproductive organs, and waste products will be disposed of. With a faulty discharge, fibroids and varices can arise. This can impede pregnancy (Ref. 41).

2.5.4. Male genital organs

In this chapter an osteopathic view on the location of the male reproductive organs will be given, and possible influences and effects will be enumerated. The influence of castration will be discussed in the chapter ‘external factors’; ‘scar tissue’.

As stated above, the internal genital organs are osteopathically more important than the external genital organs, because internally the genital organs have more connections to other structures.

An important structure of the male genital organs is the prostate. The prostate gland is a bi-lobed structure that lies within the pelvis just behind the bladder and directly below the rectum. It surrounds and is open to the urethra its entire length of the gland. Small tubes or ducts deposit the fluids produced by the prostate directly into the urethra as it courses through the prostate (Ref. 1,23). As seen in figure 23, the prostate lies in contact with the peritoneum and ductus deferentes too. Hormonal imbalance, or aging can cause an enlargement of the prostate. An enlarged prostate can cause difficulties with urinating (by causing pressure against the urinary bladder or urethra) and defecation (by causing pressure against the colon) (Ref. 1,23). This can lead to urinary bladder infections for example. Chronic bladder infections can lead to hip problems. See chapter 2.5.5 for more information about the link between the bladder and the hip joint.

A malfunctioning or enlarged prostate can cause tension in the surrounding fascial structures. While the peritoneum is in contact with a lot of organs, it can be explained that other viscera or structures can be influenced negatively by a malfunctioning or enlarged prostate. In this way, the link to the hip joint can be made.

An important thing to notice is that the spermatic ducts (ductus deferentes) and blood vessels supplying each of the testicles arise from within the animal's abdominal cavity. These vessels exit the animal's abdominal cavity in the region of the animal's groin, via the canalis inguinalis in each side (right and left) of the abdominal wall (Ref. 1,23). Tension or hyper tonia in the peritoneum can reduce the diameter of this canal, which can lead to impaired blood flow, congestion, fascial tension or inflammation of the organs supplied by these vessels. Tension surrounding the ductus deferentes can in theory influence the prostate and the ampullary glands through fascial connections. This can influence the ejaculation.

As seen above in the chapter about the female reproductive organs, osteopathic lesions in the area of the plexus aortica abdominalis or plexus mesentericus caudalis, will have negative effects on the blood supply to the reproductive organs. This of course is also possible in a male dog. The other way around, can give an inflammation of the prostate for example, a long-term afferent disturbance on the thoracolumbar transition, resulting in a osteopathic lesion of these segments. From this area, the psoas muscle group gets his innervation. In the process these muscles can get disturbed efferent information, and can become hyper tone (Ref. 37). Hyper tone psoas muscles influence the hip joint.

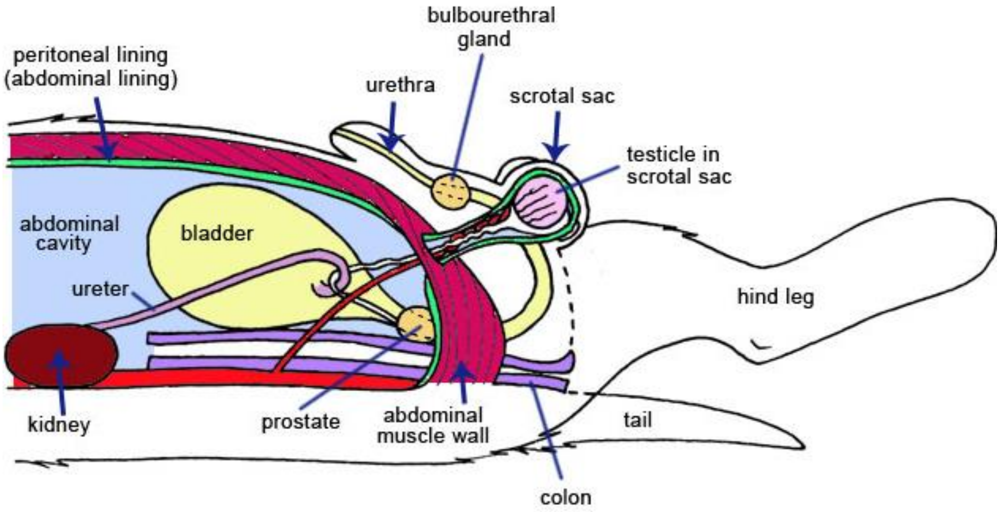


Figure 23 male genital organs and associated structures, including the peritoneum (right lateral view). Source: http://www.pet-informed-veterinary-advice-online.com/

2.5.5. Urinary bladder

The most common lower urinary tract disease in dogs over seven years of age is incontinence related to a weak urinary sphincter muscle, allowing urine to "leak" out. Bacterial infections are also common. Endocrine diseases such as adrenal disease and diabetes mellitus can predispose dogs to bacterial infection of the lower urinary tract (Ref. 42).

As seen in the chapter above, about the male genital organs, an enlarged prostate can cause difficulties with urinating, and lead to urinary bladder infections in male dogs (Ref. 1,23).

Older female dogs and dogs with diabetes are especially prone to urinary tract problems. There are a few types of bladder stones that have a tendency to form under different conditions-some in older dogs, some in either males or females, and some in specific breeds under certain circumstances (Ref. 42).

The bladder is located on the m. obturator internus (Ref. 15). A chronic urinary bladder irritation affects the tone of this muscle, and it can become hyper tone. The m. obturator internus has an abducting function in the hip joint (Ref. 15). A hyper tone muscle will make it difficult for the animal to make adduction with the hind paws, and so the movement in the hip will be influenced. For good functioning, the hip joint needs full range of motion in all directions. Otherwise, this can lead to for example arthrosis or overload of structures.

In this chapter, the peritoneum can be used as well to explain relations with other structures. When the peritoneum becomes hyper tone, the mobility and motility of the urinary bladder could be influenced too. Tension can be transferred to the m. obturator internus, and the link to the hip joint can be made.

2.5.6. Liver

The liver is the most important detoxification center in a body. Hormones and waste products are broken down here. It has the largest contact area with the diaphragm, and ligamentous connections that can directly transmit the stresses. In humans the liver is also a key organ for emotional stress (according to Barral) (Ref. 36), but in animals any concrete conclusions cannot be drawn, because there is lack of evidence. Directly linked to the liver are the stomach, pancreas and duodenum (Ref. 1). Because the digestive organs must all work together, the whole system suffers when one organ is weakened.

In case of a malfunctioning liver, the dog will put his right paws a bit more under his body, because the sympathetic information comes from the right side of the body. At this side, there will be a higher tone (for example in the m. iliopsoas) (Ref. 43). Of course this tilt affects the hip joint.

A malfunction of the liver could cause an overload in the portal system too. When waste products and hormones aren't broken down correctly, they will cumulate in the intestines, stomach and spleen. This can lead to an overload or malfunction of these organs.

The stomach is in volume and weight smaller than the liver. They are bounded by the lig. gastrohepatica of the omentum minus. The motility of the liver specific the motility of the stomach. They both make a pendule movement around the vena cava. Therefore, a malfunction of the liver will affect the stomach directly in his motility (Ref. 35).

The liver is in contact with the diaphragm (Ref. 1,12). A malfunction, or congestion in the liver, can cause via fascial structures a hyper tone diaphragm. In chapter 2.6.2. the relationship between the diaphragm and the hip joint will be explained further.

A swollen liver, caused by overload, can give pressure on the colon ascendens. This can cause congestion in the colon ascendens at the level of the angulus hepaticus. As seen above, in the chapter about the intestines, the link to the hip joint can be made by the m. psoas major; the ascending colon and descending colon are fascial connected to the m. psoas major. With digestive problems, fascial tensions can be passed to the psoas muscles (Ref. 39,40).

Hormones regulate the activity of cells and tissues in various organs of the body. The balance of hormones produced by the body is essential to good health and well-being. The liver plays an important role in breaking down of hormones. When a message keeps circulating, because it is not broken down correctly, the system can be disrupted. This will affect the whole body, and thus the hip joint too (Ref. 41).

Malfunctioning or congestion of the liver can be caused by parasite infections for example. In chapter 2.7.2. this will be explained.

2.5.7. Neurological relations between viscera and the hip joint

As seen in chapter 1.3.1, the n. vagus is an important cranial nerve. It carries both sensory and motor fibers from and to the viscera. About 20 percent are visceral motor fibers and about 80 percent are visceral sensory fibers (afferents from all of the thoracic and most of the abdominal organs) (Ref. 1,12). Malfunctioning of viscera can cause an overload of information entering the skull through the nervus vagus. The n. vagus enters the skull through the foramen jugulare, together with the n. accesorius (or XI cranial nerve, which innervates some muscles of the neck, like the m. trapezius). Because they are in contact with each other, an overload of information in the n. vagus can affect the n. accesorius, which can cause trigger points in for example the m. trapezius (Ref. 43).

Besides, afferent information of strain on fascial wrapping of viscera, runs through the n. phrenicus. This nerve goes between the mm. scaleni (level C5-C7) to the brain. So, congestion in de liver for example, can cause an overload of information in the n. phrenicus, which can lead to hyper tone mm. scaleni on the right hand side of the neck (Ref. 43).

How these hyper tone muscles can lead to a deviating load on the hip joint, will be explained in the next chapters.

2.6. Musculoskeletal relations

In this chapter there will be discussed some hypothetic situations, which can happen when muscles cannot function optimally. Relations will be described between the canine hip and hypo/ hyper tone muscles, the diaphragm, the os hyoideum and the OAA (atlanto occipital joint).

2.6.1. M. psoas major, m. psoas minor and m. iliacus

When the m. psoas major, m. psoas minor, or the m. iliacus become hyper tone, this affects the canine hip joint. The function of the m. psoas major is flexion, adduction and exorotation of the hip when the spine is punctum fixum (the non-moving part of the joint) and the femur is punctum mobile (the moving part of the joint). When the femur is punctum fixum, the muscle provides flexion of the lumbar spine, or unilateral lateroflexion. The m. iliacus has primarily the same function. The only difference is that the m. iliacus by a fixated limb makes anteversion of the pelvis. The m. iliacus and m. psoas major are fused, and called the m. iliopsoas together. The m. psoas minor provides lateroflexion of the lumbar spine, and retroversion of the pelvis. This muscle has no direct function on the limb (Ref. 1,2,15). Hyper tone muscles affect the position and movability of the spine, pelvis and hip. A fixed lumbar spine, diminished hind limb activity and fascial tension are possible effects. Thereby, a full range of motion is necessary for good functioning of the hip joint. When this range of motion is affected, overload of structures can occur. In long term, this can lead to for example arthrosis.

Thereby, the n. femoralis passes between the psoas group after leaving the spinal canal (Ref. 1,2). When these muscles become hyper tone, it is possible that the nerve is compressed, and the m. quadriceps femoris and the m. sartorius are no longer sufficiently innervated. These muscles will become hypo tone. As a result, instability of the knee joint (with the possible result of tearing the lig. cruciatum) and patella fixation is possible. This will of course influence the hip too (Ref. 44).

As seen in the chapters above, the psoas muscle group is in contact with, and thus can be influenced by a lot of structures and organs. Therefore, in practice, this muscle group is often seen hyper tone.

2.6.2. Diaphragm

The convex side of the diaphragm is lined with parietal pleura and the fascia endothoracica. In the mediastum the heart is located. Its apex is resting on the diaphragm dome. The convex side of the diaphragm is in close contact with the lungs too (Ref. 1,12,16). In chapter 2.7.2, less functioning of the heart and lungs, as a result of parasite infections, will be linked to the hip joint via the diaphragm.

The concave side is coated with the fascia transversalis and the parietal peritoneum. This is in contact with the liver, the spleen, the kidneys, and various parts of the colon (Ref. 1,12,16). In this way, it can be explained that malfunctioning of organs, like the liver for example, can cause a hyper tone diaphragm.

The mm. psoas major and minor pass in the region of their origin through arcades of the diaphragm (Ref. 16). It is possible that rib lesions, pulmonary problems, or other visceral problems lead through the fascia to hyper tension of the diaphragm. This tonal enhancement in the arcades can be attributed to the tonus of the m. iliopsoas. This results in the already mentioned symptoms such as a fixed lumbar spine, diminished hind limb activity, fascial tension and a changed range of motion of the hip joint.

2.6.3. Muscle tension in general

Not only a hyper tone psoas group can influence the hip and hind paw. When there is too much tension in muscles of the shoulder and front paws, the dog cannot use these paws correctly. As a result, other muscles will have to work harder, and compensate. A possibility is overload of the hind limb.

When there is more muscle tension on one side of the body, the posture of the body will be influenced. In this case, the paws have to move a little bit to abduction, adduction of circumduction when the dog wants to walk straight ahead. The function of the hip joint is mostly flexion and extension (Ref. 1). When other movements have to be made constantly, this will possibly cause arthrosis or irritation in the joint.

As stated above, even hypo tone muscles can affect the hip joint. Hypo tone muscles will cause instability of the joint. When a joint is instable, there can be an overload of the ligaments, bursae and joint capsules, while the muscles don’t function correctly. Tears or irritation is not uncommon.

Hyper tone muscles of the back, will affect movement of the spine. Less movement in the spine, means compensation in other joints, or shorter strides. Both of which provide for a change in movement in the hip joint.

2.6.4. OAA and os hyoideum

In this chapter the relation between the OAA/ os hyoideum and the canine hip will be described. Every structure in the body is connected to other structures with fascia (Ref. 18). So when there is too much tension at one side in the OAA or around the os hyoideum, there can be a secondary compensatory tension difference in the rest of the body.

Less movement of the os hyoideum can give tension in the muscles between the os hyoideum and the skull. The m. occipitohyoideus is very important in this case. This muscle lies between the stylohyoid and the processus jugularis (Ref. 45). When this muscle is hyper tone, the muscle at the other side of the processus jugularis, the m. rectus capitis lateralis, can become hyper tone too. The m. rectus capitis lateralis insert on the ala of the atlas (Ref. 46). Hypertone muscles can lead in time to an osteopathic lesion. Under the ala of C1 lies the ganglion cervicale craniale (Ref.12). An osteopathic lesion of C1, can in theory influence the ganglion cervicale craniale. Moreover, an osteopathic lesion of the OAA complex can cause a dysbalance between the parasympathetic and orthosympathetic nervous system; the ramus jugularis is a branch between the ganglion cervicale craniale, in the direction of the foramen jugulare, to the n. vagus (Ref. 47). So tension of the OAA and os hyoideum can be transferred to the ganglion cervicale craniale, and in this way to the n. vagus. As seen in chapter 2.5.7. the nervus vagus can be linked to the hip joint. Hypothetically, the os hyoideum and OAA can influence the canine hip joint in this way. However, this can’t be substantiated with literature.

2.7. External factors

There are a lot of external factors which can influence the homeostasis in the dog's body. For example, long nails can affect the natural alignment of the joints and bones in the paw. The adjusted position of the dogs paw will give increased tension in the flexor muscles. This can affect the canine hip. When the femur is not properly centered in the acetabulum, by abnormal muscle tension or an abnormal position, this can cause long term pathologies, for example arthrosis (Ref. 48).

It is quite clear, that continuously slipping on laminate flooring can have a negative effect on the dogs hip joint too (this can cause overload or trauma).

In the next chapters, the effects of sport, nutrition, parasites, trauma's, scars and stress will be described. The relationship between each factor and the canine hip joint will be discussed too.

2.7.1. Stress

Small amounts of stress may be desired, can be beneficial, and even healthy. Excessive amounts of stress, however, may contribute to bodily harm. Stress can be external and related to the environment, but may also be created by internal perceptions that cause an individual to experience anxiety or other negative emotions surrounding a situation, such as pressure, discomfort, etc., which is then felt as stressful (Ref. 49).

This physiological stress response involves high levels of sympathetic nervous system activation, often referred to as the "fight or flight" response. The response involves pupil dilation, release of endorphins, increased heart and respiration rates, cessation of digestive processes and secretion of adrenaline (Ref. 49).

A dog can become stressed for a variety of reasons. For example, other dogs, being left alone, food, anger owners. Signs of stress can be barking, licking, trembling, panting, destroying household items, etc. (Ref. 49).

Keeping in mind the physiological reaction to stress, it is clear the immunity of the body is decreased, so problems and diseases will occur sooner (Ref. 49). Stress can't be the cause of problems, but it can act like a catalyst.

2.7.2. Parasites

It is fairly common for a dog to become infected with an internal or external parasite at some point in its lifetime. Parasites can affect a dog in a variety of ways, ranging from simple irritation to causing life-threatening conditions if left untreated (Ref. 50).

Intestinal parasites are one of the most common problems veterinarians see in dogs. Although pets of any age can carry them, they can be a health a problem primarily in young dogs, dogs whose life style increases their risk of exposure, dogs living in sub-standard conditions and dogs with other health issues (Ref. 50).

The more common intestinal parasites have adapted so well to their hosts, that they are living in balance and cause no observable health issues. But that can always change. It is when the parasites become too numerous for one reason or another that the dog's health is affected (Ref. 50).

A few of the common intestinal parasites of dogs do not cause health issues. Some, like roundworms and tapeworms, absorb nutrients through their skin and do not normally injure the intestine. Others, however, like hookworms, chew and erode the lining of the intestine. Strongyloides tunnels through the lining causing inflammation. Single-celled giardia parasites block nutrient absorption and is thought to produce a mild toxin, while coccidia parasites enter and destroy the cells of the villi that allow nutrient absorption from a dog's intestine.

Normally, a dog has great potential to brush off the effects of a few parasitic organisms. But when the number of these parasites is high, the pet's health will suffer. Resulting diarrhea, gives less time for food absorption. Intestinal irritation lessens appetite and causes vomission and burrowing parasites cause blood loss and anemia. Intestines respond to parasite irritation by secreting mucus and by atrophy of the villi (Ref. 50).

Dogs can become infected with parasites by eating contaminated food. Normally, the composition of acids and other substances, in combination with the immunity and defence function of the body, will keep the number of parasites under control. However, when the composition of substances is changed, or the immunity and defence function is affected, the parasites can become too numerous, and thus dangerous (Ref. 50).

Reduced blood flow to the intestines (reduced removal of waste products, and reduced supply of nutrients); changes in motility and mobility of organs (so they cannot perform their function optimal anymore) and pathologies (affecting the immune system), can change the internal environment, and thus increase the number of parasites.

The heartworm is an important parasite of the dog. The adult worms are 12-30 cm long and live in the right ventricle of the heart and in the pulmonary arteries. The presence of large numbers of heartworms does both mechanically interfere with the circulation through the heart and lungs, and induces endarteritis with severe intravascular changes. Such heavy infection invariably leads to circulatory and respiratory distress. Chronic infections lead to insufficiency of the right part of the heart, which results in passive congestion of the liver, spleen and lungs, ascites and peripheral edema. The final stage of congestion failure of the heart is only seen in a small proportion of affected dogs. Also described in very heavy infections is the "liver failure syndrome" caused by worms which have invaded the vena cava and hepatic veins (Ref. 51).

Other worms, schistosomes, live in the vv. mesentericae and vv. hepaticae of their hosts. The presence of adult worms in the veins does not induce reactions of the host, except when dead worms are occasionally blocked into small veins of the intestine or swept into the liver where they give rise to focal inflammatory reactions (Ref. 51).

Figure 24 Heartworms in a canine heart. Source: http://chaskavalleyvetclinic.com/

Worms and other parasites can affect the functioning of the viscera in a negative way. The resulting fascial tension can be passed to other tissues. As seen in chapter 2.5, the intestines and liver can be linked to the hip joint.

While the heart and lungs are in close contact with the diaphragm (Ref. 12), fascial tensions can be passed to the diaphragm. The diaphragm is in contact with the m. iliopsoas. In this way, heartworm infections can affect the movability of the canine hip joint (see chapter 2.6.2 for more information about the link between the diaphragm and the hip joint).

2.7.3. Sports and trauma

Probably dogs which are used for the sport, bite work, or police/military work, have a higher risk of traumas or injuries than dogs which are pure kept as companion animals. Dogs which are not bred for jumping, running, and strenuous physical exercise, have an even greater risks of injuries when they are used for sport or work. Great Danes aren't bred to jump a lot, and pug dogs aren't bred to run far. When they have to, this can lead to overload of muscles and joints, which can directly or indirectly affect the hip joint of the dog.

Little is known about the risks of injury to dogs participating in bite work, police/military work, and various sports; for example the relatively new sport of canine agility. Levy, Hall, Trentacosta and Percival (2009) did a retrospective survey of injuries occurring in dogs participating in canine agility. Of the 1627 dogs included in the study, 33% were injured, and of those 58% were injured in competition. Most injuries occurred on dry outdoor surfaces. Border Collies were the most commonly injured, and injuries were in excess of what would be expected from their exposure. For all dogs, soft tissue injuries were most common. Dogs were most commonly injured by contact with an obstacle. According to Levy and all (2009), the A-frame, dogwalk and bar jump obstacles were responsible for nearly two-thirds of injuries that resulted from contact with the obstacle. The shoulders and backs of dogs were most commonly injured (Ref. 52). To draw well-founded conclusions, more research need to be done. When shoulder and back problems are common injuries in this sport, hip problems can occur as a result. As seen in chapter 2.6, injuries of the front paws can affect the movability of the hip joint. As seen in the chapters above, osteopathic lesions in the spine, can affect the hip joint in different ways; the orthosympathetic information to the hind limb can be disturbed, and biomechanically, less movement in the spine can cause overload on the hip joint, and the surrounding muscles. Thereby, osteopathic lesions in the spine, can result in less functioning of viscera. As seen in the chapters above, a lot of organs can be linked to the hip joint.

When first beginning training in flyball, dogs will run to the box and hit it directly with their forelimbs, resulting in increased stress to the forelimbs. Once trained, flyball dogs will turn on the box but always in the same direction—either right or left. This means that stress injuries are common to the carpus and tarsus early in the course of a flyball dog's career, and later the injuries are similar to those experienced by greyhounds since they, too, are always racing in one direction in the United States—counterclockwise on an oval track. (Ref. 53). As seen in chapter 2.6, injuries to the carpus and tarsus can lead to a compensatory load on the hip joint.

Thereby, dog obesity, improper bedding, dangerous play practices (for example on a slippery laminate floor), wrong use of a collar, and leash length can play a role in enlarged risk of trauma.

2.7.4. Nutrition

Whether a dog gets premium commercial food or prepared homemade meals, it is important the animal gets enough, but not too much, of protein, fat, carbohydrates, vitamins, minerals and water.

Proteins are complex molecules made up of amino acids, the building blocks of cell growth, maintenance and repair. In companion animals, one of the biggest demands for protein comes from the maintenance of fur and hair, which can use up to 30 percent of the daily protein intake, according to Barbara Fougère (Ref. 54,55).

Proteins are made up of 20 amino acids. While dogs, cats and even humans produce about half of these amino acids internally, the other half, termed "essential amino acids," should be provided by the diet. If even one of these amino acids is deficient, the body cannot make specific proteins effectively (Ref. 54,55).

Fats provide the most concentrated source of energy in the diet. They also supply the fatty acids that are important building blocks for important substances and essential to maintaining normal, healthy cells. Along with protein, fats contribute to a diet's palatability, plus aid absorption of the fat-soluble vitamins A, E, D and K. Like protein's essential amino acids, fat has its own essential fatty acids (EFAs): linoleic acid, linolenic acid and arachidonic acid. They make up an important part of every cell (Ref. 54,55).

Although dogs do not need carbohydrates because their bodies can get energy from protein and fats alone, carbohydrates that can be broken down by the digestive system and converted to glucose can also be a source of energy. (Carbs can be the main caloric source in some dog foods.) (Ref. 54,55).

Carbohydrates in the form of whole grains can provide iron, minerals and fibers as well as other beneficial nutrients. Carbohydrates can be found in vegetables and fruit, which also supply minerals, fibers, antioxidants, phytochemicals and some protein. Vitamins are also required for normal functioning of the body. They are important in the conversion of calories to energy too (Ref. 54,55).

It goes without saying that excess weight has a detrimental effect on joints. Heavier dogs are more likely to develop osteoarthrosis in for example their hip joints or knees. Thereby, intestines can become overloaded as a result of unhealthy food that's not suitable for a dog's intestines. See chapter 2.5.2 for an explanation about the relations between the intestines and the hip joint.

As indicated above, without the right nutrition, a body cannot function optimally. When for example amino acids fail, or when essential fatty acids fail, some cellular processes cannot be performed. Cell growth, maintenance and repair will be disturbed. This will affect the whole body. Organs, muscles and fascia cannot properly perform their tasks, and can become overloaded. In the course of time, this can lead to (fascial) tensions, osteopathic lesions, stress, accumulation of waste products, and so on.

2.7.5. Scar tissue

Adhesions are fibrous bands that connect one tissue to another tissue, forming a connection that physiological shouldn't be there. These bands are fibrous, meaning they are tougher and less flexible than their surrounding tissues to which they make the connection (Ref. 56).

When adhesions form between two different organs, these organs become partially fixed and therefore permanently struggle to expand, stretch, move or glide. Sometimes an adhesion can also behave like a torsion and actually constrict an organ, creating a physical osteopathic lesion. Within both of these examples, movement and physiological function is lost. Whenever there is a reduction in movement there is also a reduction in nutrient supply and reduction to toxin expulsion. Too much toxin build or not enough nutrient supply can lead to cell death. Any form of death in the body automatically triggers an inflammatory response. Similarly if there is a lack of sufficient blood supply then there is a much greater chance of infection (Ref. 56).

In the case of surgery, the natural healing process is started by inflammation. Inflammation brings all the materials needed for repair and clears the site from harmful microbes. Fibrin is then laid down to create fibrosis. Collagen is the last substance to be introduced. When collagen is laid down in thick fibrous bundles the blood supply becomes very insufficient. Collagen is very inflexible and together with the poor blood supply, it makes an area of scar tissue quite lifeless. So the vitality that was once present in the healthy tissue pre trauma (operation) becomes a rigid, tense and almost lifeless area (Ref. 56).

When surgery is performed external air will get into the abdomen and this dries out the natural lubrication and viscosity of the various abdominal organs and tissues. Often blood is split and becomes sticky, producing the same consequences. When the layers become dry or lack lubrication, this will increase the friction of movement between the layers (Ref. 56).

The other aspect here to consider is when an organ becomes unnaturally fixated its axis of movement changes. This has far reaching effects on the other organs because the organs all rotate and move to a certain rhythm. When the axis of movement changes, say at the ascending colon for example, then instantly the colon will pull away from its natural pattern of movement and therefore pull on other organs. In time this can put stress on these organs and they can be affected as well (Ref. 56).

If the axis of movement to which an organ rotates around changes, then this can also alter the dynamics of the mechanoreceptors. So if a stretch or distortion exists that shouldn't exist, then this could unnaturally trigger the mechanoreceptors. The feedback goes to the spine/brain and comes back resulting in spasms to the muscles of the organ (Ref. 56).

In the stomach, when the mechanoreceptors are triggered, the stomach begins to release hydrochloric acid (HCL). So if there is a fixation on the stomach, due to some external input, the mechanoreceptors can fire and produce more HCL acid. This increases the acid production which in time can lead to possible ulcerations. The mechanoreceptors are designed in this case to be triggered when the stomach is becoming stretched as a result of food entering it, not by other stimuli (Ref. 56).

Scars formed after a castration can influence other structures too. In the inguinal region, the fascia transversalis helps to build the fascia spermatica. Therefore, castration scars can create tension in the fascia spermatica, and the fascia transversalis. This fascia is in contact with the fascia iliaca, which covers the m. psoas and m. iliacus. In theory, fascial tension after a castration can tend to hyper tone psoas muscle group, and thus have influence on the dog's hip joints (Ref. 18). Nevertheless, in practice, it is not often seen.

When the body heals from a wound, it usually has some consequences that stick around after the healing processes have finished. The wound site is often bigger than the resultant collagen scar tissue. There is often an affected area around the scar that usually shows stiffness, reduced vitality and reduced function. By pulling, stretching, twisting or lifting an organ the tensions spreading in and around the site of scar tissue can be released. Therefore facial techniques are used (Ref. 56).

Conclusion

Osteopathy is a manual mode of treatment aiming at the correction of normal body mobility, the principle being that if body tissues are flexible no pains and aches will occur. Loss of mobility can manifest itself in osteopathic lesions, abdominal pains, or other disorders. Osteopathy distinguishes three systems: The parietal, the visceral and the craniosacral system. Those three systems interact with each other. The knowledge about the complexity of the structures and their connections is the basis of the osteopathic treatment.

The research question of this thesis was: Which structures of the canine body can influence the art. coxae? And in which way?

Application of these considerations above, repeatedly led to the same functional systems to answer the research question; the spine, sympathetic control, blood flow, fascial connections and homeostasis. Also the psoas muscle group is an important connection between the canine hip joint and other structures in the dog's body.

An osteopathic lesion which is present for an extended period of time ensures that all information leaving the segment is disturbed information. This eventually leads to hyperesthesia of the skin innervated by this segment; hyper tone autochthone muscles and other muscles, getting disturbed orthosympathetic information by this particular segment; trigger points; piloerection; disturbed sweat secretion; reduced circulation of blood and disturbed information to the viscera innervated by this segment; and vasoconstriction. In some cases, a visceral problem is the cause of an osteopathic lesion.

The viscera causing an osteopathic lesion are mostly the organs producing waste products. These are for example the kidneys, urinary bladder, intestines, liver, or reproductive organs. In most cases an osteopathic lesion will become a group lesion eventually.

The most important region in this thesis is the thoracolumbar junction. Because it is from this area that the orthosympathetic information goes to the hind limb. In this region the psoas muscles are found, and the afferent information of various organs enters the spine. In this region the fascia thoracolumbalis can be found too. This fascia is a link between the front side and the hind limbs of the animal. The fascia thoracolumbalis has a fascial chain with the lig. supraspinale, lig. interspinale, lig. flavum, and the capsula articularis of the spine. So a superficial traction or tension proceeds into the depth at every vertebral segment.

The life and the functioning of each individual cell of the body can only be ensured by an undisturbed blood flow. If the blood supply is restricted to muscle and tissue cells, the performance of muscles and the elasticity of the tissue are reduced. Not only the transport of nutrients, but also the removal of metabolic products is impaired. Reduced removal of the waste materials leads to over-acidification of the tissue and inflammatory processes can develop. If the joint capsule is less provided with blood, it will lose its elasticity and possibly produce less synovia, which would result in poorer cartilage nutrition.

The blood flow cannot be influenced directly, but it can be influenced via the orthosympathetic control of the blood vessels. Activation of the orthosympathetic system causes vasoconstriction. The vasodilatation is attributed to the reduced activity of the orthosympathetic system. The preganglionic fibers of the orthosympathetic system are formed in the lateral horns of the spinal cord.

Every body structure is wrapped in connective tissue, or fascia, creating a structural continuity that gives form and function to every tissue and organ. The body must be considered as a functional unit, where every area is in communication with another through the fascial continuum. The fascial tissue is equally distributed throughout the entire body, enveloping, interacting with, and permeating blood vessels, nerves, viscera, meninges, bones, and muscles, creating various layers at different depths, and forming a tridimensional metabolic and mechanical matrix. The fascia becomes an organ that can affect an individual's health, when movement is restricted by hyper tone fascia or scars.

When the m. iliopsoas (m. psoas major and m. iliacus) or m. psoas minor become hyper tone (for example as a result of an osteopathic lesion or a visceral dysfunction), this affects the canine hip joint mechanically. The function of the m. psoas major is flexion, adduction and exorotation of the hip. This muscle group can also provide flexion of the lumbar spine, or unilateral lateroflexion, and anteversion or retroversion of the pelvis. Hyper tone muscles affect the position and movability of the spine, pelvis and hip joint. A fixed lumbar spine, diminished hind limb activity and fascial tension are possible effects. Thereby, instability of the knee joint and patella fixation is possible by compression against the n. femoralis. This will of course also influence the hip joint.

The psoas muscle group also plays an important role in the connection between the viscera and the hip joint. The psoas muscle group is in close contact with the diaphragm. Hypertonia of the diaphragm, caused for example by malfunctioning of the heart, lungs or congestion in the liver, can cause hyper tone psoas muscles. The fascia iliaca wraps the psoas muscle group. Thus, it is in contact with the kidneys, caecum, ureter, colon ascendens and colon descendens. Fascial tension (in for example the peritoneum), as a result of a visceral problem, can be transferred to the canine hip joint by the psoas muscle group.

Malfunction of the viscera can cause hyper tone muscles in the neck via the n. vagus and n. phrenicus. Hyper tone muscles (regardless of the location in the body) can lead to a deviating load on the hip joint.

The answer to the research question of this thesis is:
Blood flow, among other systems and structures, is an essential factor for correctly functioning of the hip joint. Each individual cell of the body needs sufficient blood supply to maintain homeostasis. Osteopathic lesions influence the hip joint biomechanically, and also through orthosympathetic and motor nerves. All structures in the body are connected through connective tissue. Malfunction, or decreased motility/ mobility of viscera (especially the liver, reproductive organs, kidneys, intestines and urinary bladder) can cause osteopathic lesions, hyper tonia in connective tissue, or/and in the psoas muscle group, which can affect the hip joint. Hyper tone muscles or fascia (regardless of the location in the body), hypo tone muscles, trauma and scars can lead to a deviating load on the hip joint.

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List of figures

List of abbreviations

The following table describes the significance of various abbreviations and acronyms used throughout the thesis. The page on which each one is defined or first used is also given.

Abbreviation	**Meaning**	**Page**
Art.	Articulatio	3
Ref.	Reference	4
N.	Nervus	4
M.	Musculus	5
Lig.	Ligamentum	6
C	Cervical vertebra	6
T	Thoracic vertebra	6
L	Lumbar vertebra	6
Cy	Coccygeal vertebra	6
Nn.	Nervi	7
A.	Arteria	9
CNS	Central nervous system	10
PNS	Peripheral nervous system	10
V.	Vena	12
Ln.	Lymphonodus	15
Lnn.	Lymphonodi	15
Mm.	Musculi	18
Aa.	Arteriae	29
Vv.	Venae	29
OAA	Atlanto occipital joint	48
EFAs	Essential fatty acids	53
HCL	Hydrochloric acid	54

Samenvatting (Dutch)

Het heupgewricht (of articulatio coxae) is een belangrijk gewricht in het hondenlichaam. Dit gewricht zorgt ervoor dat de hond kan lopen, rennen en springen, en draagt een deel van het lichaamsgewicht. Tijdens bewegingen, zoals bijvoorbeeld rennen en springen, wordt de kracht op het heupgewricht vermenigvuldigd. Het heupgewricht moet in staat zijn om deze extreme krachten herhaaldelijk op te vangen tijdens intensieve fysieke activiteiten. Het heupgewricht is ook een van de meest flexibele gewrichten in het lichaam. Het heupgewricht is een synoviaal kogelgewicht gevormd tussen de os coxae en het femur.

De onderzoeksvraag van deze thesis is: welke structuren in het hondenlichaam kunnen het heupgewricht beïnvloeden? En op welke manier? Bij de ontwikkeling van deze thesis, leidde het pad herhaaldelijk tot steeds dezelfde functionele systemen; homeostase, de wervelkolom, sympathische aansturing, bloedtoevoer en fasciale verbindingen. Ook de m. iliopsoas en m. psoas minor zijn een belangrijke verbinding tussen het heupgewricht en andere structuren in het lichaam van de hond.

De belangrijkste regio van de wervelkolom voor deze thesis is de thoracolumbale overgang. Een osteopathische laesie in dit gebied zorgt ervoor dat alle informatie die het segment verlaat, verstoorde informatie is. Dit zal de orthosympathische en motorische informatie naar de achterpoot en naar verschillende organen en structuren in de abdominopelvische holte beïnvloeden. Daarnaast kan een bewegingsbeperking in de wervelkolom biomechanisch het heupgewricht beïnvloeden.

In het thoracolumbale gebied, vindt men ook de m. iliopsoas m. psoas minor. Via hypertonie van het diafragma, kan de m. iliopsoas worden beïnvloed door bijvoorbeeld stuwing of een slechte werking van de lever, het hart en de longen. Het peritoneum, en andere fasciale structuren zoals de fascia iliaca, kunnen ook worden gebruikt om het verband tussen de psoas spiergroep en diverse viscerale structuren te verklaren. Een hypertone psoas spiergroep zal de positie en de beweeglijkheid van de wervelkolom, het bekken en het heupgewricht beïnvloeden. Een stijve lumbale wervelkolom, een afwijkende belasting op het heupgewricht, en verminderde activiteit van de achterste ledematen zijn mogelijke gevolgen. Door compressie tegen de n. femoralis, kan instabiliteit van het kniegewricht, en patella fixatie ontstaan. Dit zal uiteraard de heup ook beïnvloeden.

Homeostase is het proces waarbij het lichaam constante aanpassingen maakt, om in een stabiele toestand te blijven zodat processen optimaal kunnen plaatsvinden. Dit kan alleen worden gewaarborgd middels een ongestoorde doorbloeding. Als de bloedtoevoer is beperkt naar spier- en weefselcellen, worden de prestaties van de spieren en de elasticiteit van het weefsel verminderd. Dit kan het heupgewricht rechtstreeks beïnvloeden, maar ook indirect via een verminderde werking van andere structuren zoals fascia en organen.

Alle structuren in het lichaam zijn verbonden via fascia. Fascia kan worden gezien als een orgaan dat invloed kan hebben op de gezondheid van een individu, wanneer er beweging wordt beperkt door hypertone fascia, verklevingen of littekens.

Storingen of een verminderde motiliteit en/of mobiliteit van de organen (m.n. de lever, voortplantingsorganen, nieren, darmen en urineblaas) kunnen osteopatische laesies, en hypertonie in fascia en/of de psoas spieren veroorzaken, wat de heup kan beïnvloeden.

Het antwoord op de onderzoeksvraag van deze thesis is:
Bloedtoevoer is een van de essentiële factoren voor het juist functioneren van het heupgewricht. Elke afzonderlijke cel van het lichaam heeft voldoende bloedtoevoer nodig om de homeostase te kunnen handhaven. Osteopatische laesies beïnvloeden het heupgewricht biomechanisch, en ook via orthosympathische en motorische aansturing. Alle structuren in het lichaam zijn via bindweefsel verbonden. Storingen, of verminderde motiliteit/ mobiliteit van organen (met name de lever, voortplantingsorganen, nieren, darmen en urineblaas) kunnen osteopatische laesies, hypertonie in bindweefsel en/of de psoas spiergroep veroorzaken, die invloed hebben op de heupgewricht . Hypertone spieren of fascia (ongeacht de locatie in het lichaam), hypotone spieren, trauma en littekens kunnen leiden tot afwijkende belasting op het heupgewricht.

Summary

The hip joint (or articulatio coxae) is an important joint in the canine body. It allows the dog to walk, run, and jump, and it carries a part of the body's weight. During running and jumping, for example, the force of the body's movements is multiplied on the hip joint. This joint must be able to accommodate these extreme forces repeatedly during intense physical activities. Yet the hip joint is also one of the most flexible joints and allows a great range of motion. The hip joint is a ball-and-socket synovial joint formed between the os coxae and the femur.

The research question of this thesis is: which structures of the canine body can influence the art. coxae? And in which way? During the development of this thesis, the path repeatedly led to the same functional systems; homeostasis, the spine, sympathetic control, blood flow and fascial connections. Also the psoas muscle group is an important connection between the canine hip joint and other structures in the dog's body.

The most important region of the spine, for this thesis, is the thoracolumbar junction. An osteopathic lesion in this region, ensures that all information leaving the segment is disturbed information. This will affect the orthosympathetic and motoric information to the hind paw and to various organs and structures in the abdominopelvic cavity. Besides, less movement in the spine can affect the hip joint biomechanically.

In the thoracolumbar region, the psoas muscle group (m. psoas major, m. psoas minor, and the m. iliacus) can be found. These muscles play an important role in the link between the hip joint and other structures in the canine body. Via hypertonia of the diaphragm, the psoas muscles can be influenced by malfunctioning of the liver, heart and lungs for example. The peritoneum, and other fascial structures like the fascia iliaca, can be used as well to explain the link between the psoas muscle group and several visceral structures. A hyper tone psoas muscle group will affect the position and movability of the spine, pelvis and hip joint. A fixed lumbar spine, a deviating load on the hip joint, and diminished hind limb activity are possible effects. Thereby, instability of the knee joint and patella fixation is possible by compression against the n. femoralis. This will of course influence the hip too.

Homeostasis is the process by which the body makes continual adjustments to keep itself in a stable condition and function to the best of its ability. This can only be assured by an undisturbed blood flow. If the blood supply is restricted to muscle and tissue cells, the performance of muscles and the elasticity of the tissue are reduced. This can affect the hip joint directly, but also indirectly by reduced functioning of other structures like fascia and viscera.

All structures in the body are connected through fascia, or connective tissue. Fascia can be seen as an organ that can affect an individual's health, when movement is restricted by hyper tone fascia, adhesions or scars.

Malfunction, or decreased motility and mobility of viscera (especially the liver, reproductive organs, kidneys, intestines and urinary bladder) can cause osteopathic lesions, hyper tonia in connective tissue, or/and in the psoas muscle group, which can affect the hip joint.

The answer to the research question of this thesis is:
Blood flow, among other systems and structures, is an essential factor for correctly functioning of the hip joint. Each individual cell of the body needs sufficient blood supply to maintain homeostasis. Osteopathic lesions influence the hip joint biomechanically, and also through orthosympathetic and motor nerves. All structures in the body are connected through connective tissue. Malfunction, or decreased motility/ mobility of viscera (especially the liver, reproductive organs, kidneys, intestines and urinary bladder) can cause osteopathic lesions, hyper tonia in connective tissue, or/and in the psoas muscle group, which can affect the hip joint. Hyper tone muscles or fascia (regardless of the location in the body), hypo tone muscles, trauma and scars can lead to a deviating load on the hip joint.