University of Veterinary Medicine

Department of Physiology and Biochemistry

Physiological and Behavioural Effects of Neutering Domesticated Animals

By:
Megan O'Connell

Supervisor:
Dr. Tóth István

Budapest, Hungary
2021

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Abstract

The objective of this thesis is to analyse in detail the physiological and behavioural effects of neutering domesticated animals i.e., cats and dogs. Scientific journals and articles were compared and evaluated based on these effects to determine whether neutering leads to problematic issues in the long term to justify solving current, theoretical, and perhaps singular issues. Key results found that neutering may lead to the development of neoplastic diseases such as: haemangiosarcomas, adenomas, mast cell tumours, lymphomas, osteomas, melanocytic tumours, and orthopaedic disorders like hip and elbow dysplasia, cranial cruciate ligament disease. Most undesirable behavioural issues seem to be reduced such as urine marking, aggression, roaming and fighting. There was limited research undertaken on the feline species asides from behavioural effects. Some research was outdated or contraindicated others. What this thesis will discuss is did neutering begin as a recommendation solely to prevent or decrease over population and throughout the years this became the norm and biased to veterinary medicine without fully considering the long-term effects on the health of the animal, and if it really is in their best interests.

Keywords: neutering, neoplasia, obesity, orthopaedic, epilepsy, urogenital, prostate, tumour, susceptibility, ovariohysterectomy, mastectomy, ovariectomy.

1 Introduction

Any form of neutering regardless of gender should be considered a major surgery, not only is the anatomical feature of the animal changed as well as multiple hormonal changes. Gonadal hormones are greatly important in growth and development of dogs, and yet it is widely adopted to neuter and spay canines before 12 months. It not only benefits the owner but moreover the animal and veterinary medicine itself to constantly review and change their neutering recommendations and guidelines based on the most current research available, as it is ever changing. Negative effects that have been citated recently and in the past can influence the pet/owner relationship, undesirable traits such as: neoplastic disease, orthopaedic disease, urinary disorders, undesirable behaviours, and obesity. Many of the sources of information available currently condemn the quick recommendations of neutering based on a singular issue that no other treatment route has been attempted to resolve (Bjørnvad et al., 2019).

A study by Hart et. al. found that castrating Golden Retrievers dogs at less than six months old had five times the incidence rate of developing joint disorders in comparison to intact males, neutered dogs at the age of 6-11 months had three times the incidence rate of intact males and finally neutered dogs at the ages of 2-8 years had double the incidence rate of intact males (Hart, et al., 2014). For females the rate of intact females was equal to males, females spayed at <6 months had 4x the incidence rate and females neutered at 6-11 months had twice the incidence rate (Hart, et al., 2014).

The same examination was carried out on Labrador Retrievers with a sole significance of an higher occurrence of joint disorder development if males and females were neutered below 6 months of age ($p=0.014$; 0.044 respectively) and females neutered between 6-11 months ($p=0.043$) (Hart, et al., 2014).

A separate study carried out on the likelihood of neutered German Shepherds developing joint disorders found neutering male or females of this breed when younger than 12 months old increased their chances significantly. The research showed that neutered males and females were three times more likely to acquire at least one form of joint disorder as to intact dogs (Hart, et al., 2016).

As the American Veterinary Medical Association stated, “There is no single recommendation that would be appropriate for all dogs”. There is a variety of journals covering the different consequence and aspects of neutering and spaying, some even conflicting. Every breed, sex and age of sterilisation react differently to the process.

Other alternatives that are worth consideration for pet owners are vasectomy; where the testicular tissue is kept intact and those retain all sex hormones, chemical neutering; dogs can be made sterile for a short time length by injecting zinc gluconate intra-testicularly. For female dogs the alternatives are tubal ligation; similar to vasectomy in males, dogs will come into heat and retain their sex hormones yet will not be able to become pregnant, ovary-sparing spay; where the uterus is removed and the ovaries are left untouched.

The first objective of this thesis is to ascertain that are the reasonings we put forward to clients really a relevant threat, the second is what are the consequences of neutering and finally what is the optimal age to proceed with neutering if necessary. The responsibility to educate owners and ensuring optimal animal care ultimately falls on veterinarians, as with all medical advice this should be in equilibrium to neutering recommendations, without falling biased to monetary benefits.

2 The Female Dog

2.1 An Overview Of The Female Reproductive System And Its Functions

Reproduction is defined as a progression of events starting "with the development of the reproductive system in the embryo" (Senger, 2012). Puberty is achieved when the animal is able to produce female gametes, followed by reproductive behaviour and copulation. The main components of the female productive tract include: Ovaries, oviducts, uterus, cervix, vagina and the external genitalia.

Layers of the female reproductive tract ranging from the outermost to innermost include the serosa which is a single layer of squamous cells that cover the tract, the muscularis: a double layer of smooth muscle that's made up of an outer longitudinal layer and inner circular layer. This layer gives a contractability function to the tract for transportation of secretory products, gametes and early embryos to the correct location within the tract. During birth it helps expel the foetus and foetal membranes. The next layer is the submucosa this contains blood vessels, nerves and lymphatics while also supports the mucosal layer. And finally it concludes with the mucosa, a secretory layer of the epithelium that lines all the lumens of the tract. Each has a different function for the different regions of the reproductive tract e.g. the posterior vagina is lined with stratified squamous epithelium that protects the organ during mating (Senger, 2012).

2.1.1 Embryonic Development Of The Reproductive Tract

During development of the tract it pushes against the peritoneum which causes it to fully surround the tract when it grows. This causes a portion of the peritoneum to fuse and form a double layered connective tissue that eventually becomes the broad ligament. The broad ligament is a suspensory tissue that suspends and supports the ovaries, oviduct, uterus, cervix and anterior vagina. The cranial portion of the broad ligament attaches and supports the ovary and this is called the mesovarium. Then there is the proper ligament, it is an additional supportive ligament that attaches the ovary to the uterus. The mesosalpinx is the serous part of the broad ligament that surrounds and supports the oviduct. This aids in directing the ova released at ovulation into the oviduct. In female dogs the mesosalpinx forms a nearly complete ovarian bursa that encapsulates the ovary. The Mesometrium, is a part of the broad ligament supporting the uterine horns and uterus body.

2.2 The Ovary: Its Surrounding Structures and Their Function

The ovary produces ova, oestrogen and progesterone. Oestrogen has many roles such as: growth, maturation and release of oocytes, preparation of the lower reproductive tract for mating, aids in the transport of male and female gametes towards each other, transportation of embryos at the appropriate time, aiding in preparation for parturition (lubrication of the vagina and softening of the cervix), growth and development of mammary tissue, it also changes the behaviour of the bitch so they are more receptive to mating (Harbor, 2021).

Progesterone helps maintain pregnancy (by keeping the muscle layers relaxed), inducing the endometrial glands which provides nutrition to the foetus, it suppresses the immune response to treat the foetus as a foreign entity, like oestrogen it has a role in the development of mammary glands, and it enhances the effects of oestrogen in providing outward signs of oestrus. (Harbor, 2021). The Corpus Luteum is responsible for the production of oxytocin, relaxin, inhibin and activin.

There are several different types of follicles within the ovary such as the primordial follicles these are the most immature, the egg in this layer is surrounded flattened cells and this develops into the primary follicle. The primary follicle is surrounded by a cuboidal epithelium and this will either develop into a secondary follicle or it will degenerate. The antral follicle, which is also called a tertiary follicle contains a cavity filled with follicular fluid. It has three layers, theca externa, theca interna and the granulosal cell layer. They each have their own function such as the theca externa produces androgens under the influence of LH, the granulosal cell layer has FSH receptors and is responsible for the production of oestrogen, inhibin and follicular fluid, and then when it becomes a dominant preovulatory follicle it is referred to as a graafian follicle.

The oviduct is made up of the infundibulum, the ampulla and the isthmus. Its main functions are to carry ovulated eggs and spermatozoa to the site of fertilisation. The infundibulum is the ovarian end of the oviduct and it captures the newly ovulated oocyte. As the surface is covered with fimbriae; the endings of these fimbriae expand over the ovary, which contract close to the surface of the ovary during ovulation and in turn guides the oocyte into the ampulla of the oviduct, this is the main site of fertilisation. Then the ampulla merges with the isthmus, and the isthmus is connected to the uterus.

2.3 Puberty in the Female Dog

The onset of puberty in the female dog on average is at 6-9 months old but in some breeds can be up to 24 months. They are a seasonally monoestrous species with one oestrous cycle per breeding season, the amount of oestrous cycles bitches can have annually are from 1-4, with small breeds having more and large/giant breeds less. The stages in each cycle are; anoestrous, proestrus, oestrus and dioestrus. Typical signs of puberty in the female dog are swelling and discharge of the vulva as well as frequent urination.

2.4 Typical Oestrous (Heat) Cycle for a Female Dog

It begins with proestrus, this is the start of heat, it lasts between 7-10 days. The vulva will swell and females will attract males however they will not accept mounting. The next stage is oestrous, here the mating period will last from 5-10 days. Females will attract and accept males, and then ovulation occurs around 2-3 days after mating. The third stage is dioestrus, this will start 10-140 days after heat, here the female should be pregnant or in the resting phase. Anoestrus is the final stage which is a resting period between diestrus and the next heat cycle. In this stage the ovaries are inactive, uterine involution and endometrial repair occurs and lasts typically 1-6 months.

2.4.1 Physiological Changes During a Female Dog's Heat Cycle

In anoestrus there is a deterioration of luteal function, and a decline of prolactin secretion**.** As well as this there is an increase in secretion (pulsatile) of pituitary gonadotrophins, FSH, LH induced by GnRH. Hypothalamic GnRH secretion is pulsatile as intermittent secretion is required for gonadotropin release. So during anoestrus FSH moderately increases, LH slightly increases and in late anoestrus a pulsatile release of LH increases.

In proestrus the vulva is slightly enlarged, FSH and LH levels are low during most of this cycle, and a rise during the preovulatory surge occurs. Oestrogen levels also begin to rise, peak levels occurring late proestrus (2–10 - 50–100 pg/mL), progesterone will remain at basal levels until rising with LH surge, this lasts 3-21 days with 9 days on average. The follicular phase of the ovarian cycle coincides with proestrus and very early estrus.

In oestrous there are decreasing oestrogen levels and increasing progesterone levels, serosanguineous to hemorrhagic vulvar discharge may diminish and vulvar oedema is at maximum. In the luteal phase of the ovarian cycle; when oestrogen decreases after LH peaks,

and progesterone steadily increases. Primary oocytes ovulate 2–3 days after the LH peak, and oocyte maturation is seen 2–3 days later, the life span of secondary oocytes is 2–3 days. In dioestrus the vulvar discharge diminishes and the oedema will resolve. There is a diestrual shift which shows a reappearance of parabasal epithelial cells and neutrophils. At this stage of the cycle oestrogen levels are low, progesterone rises to a peak and then a decline in late diestrus. Secretion depends on pituitary LH and prolactin secretion.

2.5 The Spaying Procedure

As with an elective surgery it is imperative you know what it contains, in an OHE/OE we are changing the anatomical structure of the dog, the surgeon will go deep into the abdominal cavity and break certain features in order to remove the ovaries and possibly the uterus. It is imperative to bear in mind the possibility of certain mechanical damage whilst operating with tools around such delicate areas. In an ovariohysterectomy the surgical objective is the removal of the uterus and ovaries (Birchard and Sherding, 2006). Reasonings for the procedure is to prevent oestrus, prevent unwanted offspring, the prevention or treatment of: pyometra, metritis, neoplasia (uterine, ovarian, vaginal), ovarian cysts, uterine torsion or prolapse. In the surgical technique an incision is a 4-8cm cut depending on the dog itself. The cut is through the skin and subcutaneous tissue, and into the abdominal cavity. An ovariectomy hook is inserted 2-3cm caudal to the kidney, then you can turned medially to capture the uterine horn, broad ligament or round ligament. The suspensory ligament near the kidney is broken without damaging the ovarian vessels. The surgeon should make a hole in the broad ligament caudal to the ovarian pedicle, this allows you to place 1-2 forceps across the ovarian pedicle proximal to the ovary and one across the proper ligament of the ovary, this will prevent backflow of blood after transection (Kumar, 2010). A ligature with a double knot is placed where the first forceps was clamped, and another ligature can be placed just below, then a cut is made between the middle clamp and the ovary. Ligatures should be an absorbable suture material. The severed stump is monitored for haemorrhages, once satisfied it can be returned to the abdomen (Fossum, 2013). Once that ovary has been severed the other is removed in an identical technique. The surgeon will trace the uterine horn into the body, exteriorise the uterine body and ligate it in two places adjacent to the cervix, and encircles the uterine vessels on each side (Fossum, 2013). The body of the uterus is clamped and the uterus severed, the uterine stump is checked for haemorrhages (Kumar,

2010), after the uterus has been removed the abdominal cavity is checked for any haemorrhages, then the abdomen is closed (Birchard and Sherding, 2006).
Contraindications of this procedure is any generalised condition with hypothermia, dehydration, mydriasis (Bencharif et al., 2010).

Complications of this procedure can include; ovarian artery haemorrhage, surgical would haemorrhage, wound healing complications, urinary incontinence, ovarian remnant syndrome leading to uterine stump pyometra (White and Muraro, 2014), haemorrhages can be common in obese dogs, fistulous tracts and granulomas, eunuchoid syndrome and complications of celiotomy (Birchard and Sherding, 2006). Complications are a real occurrence with one retrospective studying an average of 7.5% of complications in OHE procedures (White and Muraro, 2014), which is a higher prevalence than brucellosis or ovarian neoplasia. This is an exclusion of intra-anaesthetic or post-anaesthetic complications which have their own complication rates alone, the mortality rate of healthy patients is 0.05-1% (Truchetti, 2015). An audit in the UK done on spaying complication rates showed that at least 25% of operations "resulted in some form of complication", including fatality (RCVS Knowledge, 2019).

The objective of an ovariectomy is the removal of the ovaries, procedure reasonings are similar if not the same as an ovariohysterectomy. This procedure is contraindicated if the uterus is damaged or diseased e.g. pyometra, hyperplasia, neoplasia, torsion, prolapse, rupture etc. The limitations of an ovariectomy is that they should be performed in young, healthy females with a healthy uterus. OHE should be carried out in the case of older females.

2.5.1 A Comparison of Ovariectomy (OE) vs Ovariohysterectomy (OHE) procedures

OE has a shorter incision and less invasive in comparison to OHE. Therefore less recovery time or wound complications. The risk of damaging ureters in OE is non-existent compared to OHE. There is no occurrence of stump pyometras in an ovariectomised animal, unless an ovarian remanent has been left resulting in pyometra, and finally there is a shorter time under anaesthesia compared to an OHE.

3 The Female Cat

3.1 The Oestrous Cycle

Female cats are induced ovulators i.e. they do not ovulate unless they are bred. This increases chance of conception, queens are seasonally polyoestrous meaning they have multiple cycles during a breeding season. They should have their first heat at 4 months old with 2-3 heat cycles during the breeding season (Feb-Oct). Signs of heat include rolling/rubbing against objects, kneading hindlimbs, yowl loudly/repeatedly. These signs can last 3-20 days and repeat in 10-40 days if not bred. Their gestation period lasts 60-63d (2m) with an average litter of 4 kittens. Signs of pregnancy in felines include a large abdomen, increased appetite, swollen mammary glands. Pseudo/false pregnancy can show signs of nesting.

3.2 The Spaying Procedure

Surgical procedure of OE and OHE are very similar in cats and dogs. The same method of sterilisation in bitches can be applied to cats.

4 The Male Dog

4.1 An Overview of The Reproductive System and Its Functions

The main components of the male reproductive system are as follows: the spermatic cord, the scrotum, the testis, the excurrent duct system, the accessory sex glands, and finally the penis and its muscles.

The spermatic cord connects the testis to the body, it extends from the inguinal ring to where it attaches on the dorsal pole of the testis. Within the spermatic cord you will find the ductus deferens, cremaster muscle and the pampiniform plexus. The spermatic cord has many functions for example: it contains the cremaster muscle, provides a heat exchanger, gives a vascular, lymphatic and neural connections to the body (Senger, 2012).

The scrotum is made up of four layers: the skin, the tunica dartos, the scrotal fascia, and the parietal vaginal tunic. It functions as a thermosensor, swamp cooler, protective sac. It can act as a thermosensor as the skin on the scrotum is made up of many sweat glands. These glands are important in regulating testicular temperature. When a high body or scrotal temperature is reached the hypothalamus sends nerve impulses to the sweat glands. Sweating acts as a swamp cooler as it can cool down by evaporative heat transfer. The scrotum has many sensory nerves that regulate scrotal sweating and the respiratory rate of the animal. This can have a major impact in some animals e.g. Merino rams (Senger, 2012). The main function of the tunica dartos is that it can maintain sustained contractions which holds the testes close to the body during cold temperatures. It also relaxes during hotter climates to aid in cooling. The ability of the tunica dartos to contract in castrated males is withdrawn due to absence of testosterone.

The primary function of the testes is for the production of spermatozoa, hormones, proteins and fluids. Their main by-products are: spermatozoa, testosterone, inhibin, oestrogens and other proteins needed for the function of sperm, seminal fluid. The purpose of the seminal fluid is to transport the spermatozoa from the testes. A blood-testis barrier is formed from the cells around the seminiferous tubule and Sertoli cell junctional complexes, this prevents autoimmune reactions from destroying developing germ cells. This is important as immune cells and immunoglobulins would recognize the development of germ cells as foreign as they go through meiosis.

In the excurrent duct system, spermatogenesis takes place in the tubulus contortus portion of the seminiferous tubules. The contraction of cells in the tubule and the flow of fluid

secreted by the Sertoli cells aids the movement of new spermatozoa into the rete tubules. These Sertoli cells are the 'governors' of spermatogenesis, meaning they host a large number of developing germ cells. Testis with a high number of Sertoli cells produce a large number of spermatozoa. Sertoli cells contain receptors for FSH and testosterone, they also produce: androgen binding protein (ABP) which is a testosterone transport protein, Sulfated Glycoproteins (SGP) 1 and 2, an iron transport protein needed for spermatogenesis called transferrin, and a suppressor of FSH known as inhibin.

The efferent ducts merge and form the epididymal duct, the role of the efferent ducts is to move new spermatozoa and tubular fluid into the epididymal duct. Finally the primary function of the epididymis is to give a suitable environment for the spermatozoa to mature, allowing suitable motility and in turn fertility. Another function of it is as a storage unit for spermatozoa. The function of these are all androgen dependent.

Accessory Sex Glands in the dog and cat differ in that the male dog has solely prostate glands, these lie in the between the bladder and pelvic urethra. The male cat has prostate glands and two bulbourethral glands (Miller, et al., 2013). The function of the prostate is to produce some of the fluids found in the semen, and the role of the bulbourethral glands are to give mucous proteins, these lubricate the urethra and neutralize leftover urine from the urethra (Miller, et al., 2013). These glands are testosterone dependent to function and maintain structure, ergo when it is absent the weight decreases.

The penis is made up of three parts: the base, the shaft and the glans penis. It is the copulatory organ of the reproductive system. The glans penis has many sensory nerves and is responsible for ejaculation upon stimulation. The main species difference is in the male cat where the glans penis is covered with spines, these are also androgen dependent and dissipate once the animal is castrated.

The cremaster muscle is a striated muscle that runs in continuum with the internal abdominal oblique muscle. Its function is to support the testes and helps control testicular temperature. It helps regain temperature control through its pumping action by contracting and relaxing on the pampiniform plexus which helps blood flow and aids in cooling efficiency.

Vascular heat exchange happens as the testicular artery and pampiniform plexus work together to regulate the thermal dynamics of the testis. There is a gap of approximately 6C between the testis and the body. The arterial blood is about 39C, it comes from the body and is cooled before it reaches the testis as they lay close to the veins that are returning cooler blood at 33C (Senger, 2012). The blood in the veins are cooled by direct heat loss from the veins through the scrotum. This is all to allow spermatogenesis to occur. Hot persistent

temperatures show a reduction in sperm motility and that eggs fertilised by these sperm had a low incidence of survival (Senger, 2012).

Testosterone is produced in the Leydig cells of the testis. There is an exchange of testosterone between the venous and arterial blood supply due to their close nature (Senger, 2012). It moves from an area of high concentration to low and therefore moves from the vein to the artery. It has a similar exchange system in females where PGFa is exchanged between the uterine vein and ovarian artery.

4.2 Puberty In The Male Dog

Puberty onset in the males is typically around 6-18 months depending on the size and breed of the dog with typically larger dogs developing later. Symptoms of puberty are marking their territory and roaming, most males will respond to females in heat at any time however they are most fertile when fully mature.

4.3 The Neutering Procedure

For an orchiectomy the surgical objective is the removal of the testes. Indications for the procedure are; reduction of overpopulation, decrease of male aggressive behaviours, decrease of roaming, reduction of undesirable urination behaviour, prevention of androgen-related diseases such as: prostatic and perianal diseases, adenomas/hernias, congenital abnormalities, testicular/epididymal abnormalities, scrotal neoplasia, trauma, abscesses, inguinal-scrotal herniorrhaphy, scrotal urethrostomy, epilepsy control, control of endocrine abnormalities (Fossum, 2013).

There are different surgical techniques for canine neutering, a prescrotal or perineal approach can be used. For an example an open prescrotal castration is as follows, once prepared pressure is applied to the scrotum to push the testicle into the prescrotal area. An incision is made through the skin and subcutaneous tissue along the median raphe over the displaced testicle. The spermatic fascia is cut to exteriorise the testicle, an incision is made through the parietal vaginal tunic. The vaginal tunic is clamped where it attaches to the epididymis, then the ligament of the epididymal tail is separated (most often torn by hand). The vascular cord and ductus deferens are then ligated and the cord clamped. The ductus deferens are cut after this a ligature is placed around the cremaster muscle and tunic.

The second testicle is removed as described above and the patient is closed as routine (Fossum, 2013). Scrotal ablations are indicated for neoplastic scrotal diseases, or for canines

with scrotal urethrostomy or perineal urethrostomy in cats, other uses for this method include; scrotal trauma, abscesses, ischemia (Fossum, 2013).

An audit undertaken in 2018 in the UK to reveal the complication rates of neutering revealed that 8.2-9.1% of call cases showed abnormalities that needed treatment or surgical intervention, fatality occurred in 0.1% of dogs (RCVS Knowledge, 2018).

4.4 Chemical Castration

A non-surgical form of neutering is chemical castration, this is a temporary non-surgical method of neutering. A suprelorin implant is implanted subcutaneously lasting for approximately 6 months. Taking 1 month to be effective for the first implantation. It is a relatively painless procedure that does not require anaesthesia. The implant slowly releases Deslorelin, this suppresses the function of the pituitary gonadal axis, making the animal infertile. There is no need for removal of the implant as it is broken down by the body harmlessly. Side effects can include, swelling at the site of implantation, diet and activity level changes, changes to the coat.

4.5 Chemical Castration Vs. Orchiectomy

Both methods have the same outcome with the major difference in being one method is permanent and one is reversible. Therefore if there is undesirable behavioural effects such as anxiety or changes to the dogs physical appearance chemical castration would be more suitable. Chemical castration is preferable in a case where a dog has health conditions making an anaesthetic a risky procedure.

5 The Male Cat

5.1 Puberty

Male cats should reach sexual maturity between 5-7 months old.

5.2 The Neutering Procedure

The site is surgically prepared as normal with dorsal or lateral recumbency used, pressure is applied to the testicle within the scrotum to immobilize it and an incision is made over the testicle from cranial to caudal. The parietal vaginal tunic is incised and the testicle exteriorised and the attachment of the ligament of the epididymal tail to the vaginal tunic will be digitally separated by the surgeon, then the spermatic cord is doubly ligated, or tied in a figure-eight knot and transected. The second testicle should be done in an identical fashion, resection of the tissues protruding from the scrotum occurs and the scrotal incision should heal by secondary intention. Complications of neutering in cats include scrotal bruising/swellings, haematoma or seroma near the scrotum, adhesions, skin infections.

6 Most Common Considerations For Spaying Bitches

The most common considerations for spaying female dogs are as follows, below I will discuss the evidence based research of each:

6.1 Brucellosis

As discussed below in male dogs, the findings are still the same. It is only prevalent in some countries, it is zoonotic but with no detrimental effect on human welfare, neutering will only decrease the risk. A more effective route for eradication or controlling the spread of such an infectious disease is travelling checks in regards to transporting dogs intercontinentally.

6.2 Pyometra

Pyometra is characterised as a "secondary infection that occurs as a result of hormonal changes in the female's reproductive tract" (Ward and Weir, 2009). It develops as a consequence of "repeated progesterone exposure during the luteal phase" of the oestrus cycle (Hagman et al., 2014). It is most commonly occurring in older dogs but can effect female dogs of any age, the preferred route of treatment is an OHE. Pyometra can be an open-cervix or closed-cervix pyometra, the fundamental difference being that an open-cervix has purulent and bloody discharge from the vulva and none in a closed-cervix pyometra. A closed-cervix pyometra is more severe form and potentially life-threatening, the abdomen can swell or become distended as the uterus may fill with fluid. Average ages for bitches with open pyometra is 9 years old and 9.6 in the case of closed-cervix pyometra (Jitpean et al., 2016). A closed pyometra is widely proven to be more fatal as the pus that is produced is unable to drain, it will gather in the uterus and the bacteria can release toxins into the bloodstream and therefore can lead to more complications e.g. septicaemia, systemic sepsis, endotoxic shock and possibly a systemic inflammatory response syndrome (SIRS) that will lead to organ failure (Pratschke, 2017). For entire bitches under the age of 10 it accounts for 25% of reported diseases (Jitpean et al., 2014), this statistic is confirmed in a retrospective study done on Swedish bitches (Egenvall et al., 2001).

Pyometra can still occur in spayed bitches, with a similar pathogenesis, this is called uterine stump pyometra. This is where the dog has gotten a complete OHE i.e. the uterus and ovaries have been removed, however in this incidence some remnants of ovarian tissue and some uterine tissue have been left behind (Crane, 2009).

The prevalence of pyometra forms are as follows 61.8% of bitches have an open-cervix pyometra and 38.2% have a closed-cervix pyometra (Lee et al., 2016). The fatality of canine pyometra is typically 3-4% (Hagman et al., 2014).

With all this conclusive evidence, pyometra is a very real health risk to bitches. The time of spaying is however not focused on, with the prognosis of open pyometra being very good (75-90%), and closed-cervix less so (25-40%) (Central Texas Veterinary Specialty & Emergency Hospital, 2019), spaying is a good prophylactic treatment in the incidence closed-cervix pyometra will occur.

6.3 Ovarian Neoplasia

There is limited research on the study of ovarian neoplasia in the bitch. Some research dictates a prevalence of 0.5-6% (Dow, 1960), more current research dictates it is less than 1% in intact bitches (Stoewen and Pinard, 2020). Most ovarian neoplasia are malignant such as teratocarcinomas, carcinomas and adenocarcinomas, the cause of these is not well understood and is currently alluded to a mixture of genetic and environmental factors. It most commonly seen in older, intact bitches, with metastasis ensuing in 20-30% of cases (Stoewen and Pinard, 2020). Spaying is the most pursued treatment in regards to benign or local tumours, other avenues would have to be explored in the incidence of malignant neoplasia.

6.4 Mammary Neoplasia

The prognosis of Mammary tumours (MTs) is heavily dependent on treatment, with sterilisation or bilateral radical mastectomy being successful and a partial mastectomy being less so as the reoccurrence rate is high (Beaudu-Lange et al., 2021). Research dictates that MTs occur in 35% of female dogs with a fatal prognosis in half of these bitches, it also states that the prevalence of MTs in dogs neutered before 2 years of age was very low in contrast to older and intact bitches (Beaudu-Lange et al., 2021).

7 Most Common Considerations for Castrating Dogs

The most common considerations for neutering male dogs are as follows, below I will discuss the evidence based research of each:

7.1 Prostatic Disorders

7.1.1 Benign Prostatic Hyperplasia (BPH)

Benign Prostatic Hyperplasia (BPH) is a common disorder of the prostate in male dogs, which is attributed to "androgenic stimulation or an altered Androgen:Oestrogen ratio" (MSD Veterinary Manual, n.d.). Some breeds have a genetic predisposition to developing BPH e.g. the Bernese mountain dog, the German Pointer, the Scottish Terrier and the Bouvier des Flandres (Teske et al., 2002). It is often stated that BPH is presented largely or microscopically in 100% of all male intact dogs, and in 50% of male dogs by four years of age. However one study examined 820 male dogs over the age of four years and detected BPH in only 0.05% (Sridevi et al., 2012). A more recent study also concluded without castration, BPH is very likely seen in dogs over the age of six (Christensen, 2018), this article also discussed that castrated male dogs are more likely to develop prostate cancer.

The development of prostate cancer in dogs is rare, transpiring in around 0.3-0.6% of dogs (Vin.com, 2016), they are almost always high metastatic cancers, very progressive and have a poor prognosis. The fact that castrated dogs are more likely to develop prostate cancer is minimally discussed, with the OR increasing in each subsequent journal, the OR was noted previously at 2.38 (Bell et al., 1995) and more currently 4.34 (Teske et al., 2002). The main conclusion regarding prostate cancer is that whilst it may not trigger the initial development of prostate cancer it would in fact aid in tumour progression.

7.1.2 Prostatitis and Prostatic Cysts

Prostatitis is an inflammation of the prostate gland, it can be acute or chronic, which occurs secondary to BPH. It can be bacterial or aseptic, bacterial prostatitis is thought to be most common in older dogs with BPH and very rare in castrated dogs as the prostate gland has atrophied (Harris, 2015). Prostatic cysts are fluid filled cysts, which are abnormal tissue remnants from embryonic development (Llera, n.d.), they often do not cause any harm until the dog is several years old and can have bacterial infections, these are often seen in conjunction with BPH and are once again very rare in castrated dogs (Harris, 2015).

7.2 Brucellosis

Brucellosis is caused the bacterium Brucella canis (B. canis) which dogs are the definitive host of. Mode of transmission venereal and ingestion of contaminated materials, this is a zoonotic disease however it is not deadly and very rare (Nicoletti, 2016). While brucellosis in dogs is technically worldwide it mainly affects America, Asia and Africa, it is very rare in Europe, the UK or Canada (Hensel, et al., 2018). Neutering will only reduce the risk of a castrated dog developing brucellosis, even if an infected dog gets neutered there is no evidence to suggest neutering would eliminate or even reduce the risk of transmission, as the bacteria is still in the body and a mode of transmission can be through urine.

7.3 Testicular Cancer

There are multiple factors that contribute to cancer in the canine species. Factors such as family history and genetics, age (predominantly in older dogs), environmental carcinogens such as UV radiation, second hand tobacco smoke, herbicides, pesticides, air pollution, nickel, uranium, benzidine etc., and viruses (Merck Veterinary Manual, n.d.). The most commonly seen cancers in dogs are as follows, lymphoma, MCT, osteosarcoma, melanoma, mammary gland carcinomas, HSA (www.aaha.org, n.d.).

The most common testicular tumours are Sertoli Cell Tumours (SCT), Interstitial Cell Tumours (ICT) and Seminomas (SEM), an experimental study done in 2006 carried out necropsies on 232 dogs (purebred and cross breeds) with 27% of these having one or more testicular tumours, in order of prevalence being ICTs, SEMs and SCTs (Grieco et al., 2008). SCT and ICT have an excellent prognosis, and SEM without hyperestrogenism also has a very good prognosis (BluePearl, 2017). The supported treatment for testicular cancer is neutering, unless in the case of cryptorchism, intra-abdominal surgery is advised to see if there are metastasis (Pion and Spadafori, 2017). Evidence to suggest an intact young dog (<10 years) to develop testicular cancer is typically associated with cryptorchidism (Liao et al., 2009).

7.4 Perineal Hernia

Perineal hernia is a disorder where the pelvic diaphragm becomes weakened. The statistical prevalence of a perineal hernia in all dogs is 0.1-0.4% (Central Toronto Veterinary Referral Clinic, n.d.). It is a very uncommon disease and affects mostly intact middle-aged to older male dogs, surgical intervention is the only treatment option and the prognosis of it varies as it has a high rate of reoccurring (10-46%) (Gallagher, 2020).

7.5 Perineal Adenoma

Perineal adenoma is a type of benign tumour that originates from the sebaceous glands encompassing the anal glands. These can arise from the apocrine anal sac glands or circumanal glands. Anal sac adenomas are extremely rare and adenocarcinoma of the anal sac accounts for 2% of all skin tumours. The first method of treatment is surgical removal along with irradiation and or chemotherapy. Intact male dogs are 5-6 times more likely to be a risk to develop this particular benign tumour, in contrast they are more common in spayed female dogs which leads veterinarians to believe that female hormones play a protective role (Kessler, 2014).

8 Most Common Considerations For Spaying Female Cats

The most common considerations for spaying cats are as follows, below I will discuss the evidence based research of each:

8.1 Pyometra

Like describe in canines, pyometra is indeed fatal without treatment. Treatment options are the same as is the potential risk of stump pyometra. Prevalence of pyometra is roughly 1.7-2% (Hagman et al., 2014) of intact female cats by the age of 13, most likely because they are seasonal breeders and induced ovulators (McCallin, 2020). Purebred cats with the highest incidence rate (IR) were the Sphynx, the Siberian cat, Siamese, Ragdoll, Maine Coon, Bengal, Korat and Ocicat, and the fatality rate is 5.7% (Hagman et al., 2014).

8.2 Ovarian Neoplasia

Similar to canines, ovarian neoplasia is very rare and even less occurring than in dogs (Stoewen and Pinard, 2020).

8.3 Mammary Neoplasia

MTs are not as prevalent in cats as they are in dogs, however they have a higher malignancy rate and are more aggressive typically. OHE is a good preventative method against MTs, with prevalence in 9% of cats neutered before 6 months, 14% between 7-12 months and 89% between 13-24 months. Approximately 80-90% of MTs in felines are malignant, with adenocarcinoma the most dominant type. Standard treatment pursued is a radical mastectomy, prognosis can be poor for aggressive mammary carcinomas (Schoen, 2015).

9 Considerations for Neutering Cats

The principle reasonings for neutering male cats are to decrease roaming, fighting, unwanted urinating and decrease in strong urine odour. Research of the feline variety in terms of health effects on neutering are relatively scarce, that being said neutering is very successful in combatting these unwanted behaviours.

10 Physiological Effects of Castrating/Spaying

10.1 Neoplasias

10.1.1 Haemangiosarcoma:

Haemangiosarcoma (HSA) is a malignant tumour derived from the cells lining blood vessels, they occur commonly in dogs and account for an average 48% of all splenic malignancies (Robinson et al., 2021). They occur in the spleen, right atrium of the heart, liver, skin and subcutis. In recent research it has been documented that that spayed female dogs have five times the risk of intact female dogs for cardiac HSA and 2.2x the risk for splenic HSA (Robinson et al., 2021). Studies show that there are hormonal influence on the cause, prevention and therapy of canine cancers. Figures and data for these reports were obtained from The Veterinary Medical Database (VMDB).

The study took history and information from a sample size of 5,736 dogs diagnosed with HSA. It describes in detail the each odds ratio (OR) for splenic, cardiac and HSA in general, these ORs supports the statement that neutering increases the risk of developing splenic HSA, with cardiac HSA showing a lower than formerly documented association of neutering and HSAs (Robinson et al., 2021). The studies conclude that neutering does increase the risk of developing this particular cancer in both female and male dogs. A lapse in these studies are whether age at the time of neutering play an important effect on HSA development or if it is the cessation in sex hormones that progresses the development. Another study compiling data from the Swiss Canine Cancer Registry also supported the finding that spayed female dogs had a higher OR to develop this neoplasia when compared against intact female dogs (Gruntzig K et al., 2016). In a study carried out on Golden Retrievers there was significant finding that female neutered dogs of this breed had four times the occurrence of developing HSA than intact females. The mean ages for onset of HSA in this breed in intact, early-neutered (<12 months) and late-neutered (>12 months) were 6.4, 7.6 and 3.2 years, accordingly (Riva et al., 2013). Hart et. al. contradicted these findings in that no significance was found in comparing intact vs spayed females but did find the risk increased if they were neutered after 1 year old (Hart, et al., 2014).

10.1.2 Adenoma/Adenocarcinoma:

On a study using the swiss canine cancer registry with a sample size of approximately 121,963 between the years 1955-2008 these were the most frequent tumours diagnosed. Adenoma is a benign tumour of glandular tissue and adenocarcinomas are their malignant counterpart. Research found that specific breeds such as Yorkshire terriers, poodles, cocker spaniels, collies, dachshund and west highland terriers had a much higher OR in contrast to cross breeds or other breeds (Gruntzig et al., 2016). The study also found that females had a significantly higher odds ratio for developing an adenoma/adenocarcinoma than their male counterparts. With distinction made on the neutered status of the dogs, research found that neutered male dogs had a higher OR of developing this tumour compared to entire male dogs, along with female dogs had a higher OR of developing this tumour compared to entire female dogs (Gruntzig et al., 2016).

10.1.3 Mast Cell Tumours (MCT):

A MCT is a type of tumour made up of mast cells. In the study done based on the swiss canine cancer registry the boxer breed showed a much higher OR to develop such tumours in comparison to cross breeds or other breeds (Gruntzig et al., 2016). The study also found that females had a significantly higher odds ratio for developing a MCT than their male counterparts. With distinction made on the neutered status of the dogs, research found that neutered male dogs had a higher OR of developing this tumour compared to entire male dogs, along with female dogs had a higher OR of developing this tumour compared to entire female dogs (Gruntzig et al., 2016). An investigation by Riva et. al., showed no development of MCT in intact female Golden Retrievers with a meaningful difference in the onset for early and late-neutered females, 6.2 and 6.5 years respectfully (Riva et al., 2013). In female Golden Retrievers the neutering period of 2-8 years held the most significance in occurrence of MCT ($p=0.013$) (Hart, et al., 2014).

10.1.4 Lymphoma

Lymphoma is a neoplasia of the lymphatic system, a common cancer in dogs caused by the harmful growth of lymphocytes (Fan, 2017). Lymphomas were most commonly diagnosed predominantly in the lymph nodes, then in unspecified locations, followed by blood and haemopoietic system, skin, spleen and finally the liver (Gruntzig et al., 2016). The rottweiler breed was linked as the most predisposed in comparison to others. In relation to the effect of neutering, the study found that neutered male and females presented higher ORs of developing lymphoma versus entire dogs (Gruntzig et al., 2016). Another study carried out on the incidence of this cancer on Golden Retrievers by Riva et. al. supported the finding that the occurrence of this neoplasia was higher in neutered dogs. However, there was only a statistically significance in male neutered dogs, with a rate of three times more likely to develop this cancer than intact male Golden Retrievers (Riva et al., 2013). Hart et. al. also support the findings that neutered male Golden Retrievers has a higher risk of developing lymphoma than intact males, equal significance was found in female Golden Retrievers as neutered females held more risk specifically in the neutering period of 6-11 months ($p=0.014$) (Hart, et al., 2014).

10.1.5 Osteoma/Osteosarcoma

Osteomas are benign ‘outgrowths of bone’ (Clinic, 2021) found typically growing on the skull and osteosarcomas are defined as a malignant tumour of bone where there is a proliferation of osteoblasts (Clinic, 2021). The most typical locations found were the joints and bones and breeds with the highest susceptibility were rottweilers and The Great Dane. In relation to the effect of neutering, the study found that neutered male presented a higher ORs of developing lymphoma versus entire male dogs (Gruntzig et al., 2016).

10.1.6 Melanocytic tumour

These types of tumours develop from the pigment cells within the skin, they can be malignant or benign melanocytomas (Villalobas, 2021). The order of their most dominant anatomical locations were in order as skin (93.6%) and the oral cavity/nasopharynx (Gruntzig et al., 2016). In relation to the effect of neutering, the study found that neutered female presented a higher ORs of developing lymphoma versus entire female dogs (Gruntzig et al., 2016).

10.2 Orthopaedic Diseases

10.2.1 Cranial Cruciate Ligament Disease (CCLD)

A case-control study undertaken by Duerr et. al. identifying risk factors for the development of excessive tibial plateau angle (TPA) in large-breed dogs with CCLD identified premature spaying/neutering as a risk factor. This study used 58 dogs with excessive TPAs and 58 dogs with normal TPAs used as control dogs. An abnormal TPA was defined as greater than 35 degrees and a normal as less than 30 degrees. The methods and materials were obtaining full medical records, along with radiographs and interviewing owners to determine potential risk factors for CCLD (Duerr et al., 2008). The results were as follows; "case dogs were 3x more likely to be neutered before 6 months of age as control dogs, case dogs with TPA >35 degrees in both limbs were 13.6 x as likely to have been neutered before 6 months of age as were control dogs with TPA < or = 30 degrees in both limbs". Case dogs were also substantially younger when hindlimb lameness started compared to the controlled dogs (Duerr et al., 2008).

In this study, the neutering age is very young in regards to what most veterinarians would suggest to owners in practicing clinics. However it is worth to keep in mind many shelters that's main goal/priority if to prevent over-population and has a compulsory requirement to spay/neuter dogs before adoption. This study is suggesting that large breeds in particular require a long time to reach full skeletal maturity.

The Golden Retriever study undertaken by Riva et. al. showed no incidence of CCLD in late-neutered females (>12 months), intact female or male dogs. Nonetheless, there was an important contrast in regards to early and late-neutered dogs. With an onset of 3.6 years in early neutered dogs (<12 months) and 7.4 years in late neutered dogs. Early neutered females had an onset age of approximately 4.8 years. The study found no distinction between the BCS (average of 5.8) of neutered males with and without CCLD (Riva et al., 2013).

Hart et.al. research also supported the findings that no incidence of CCLD was diagnosed in intact Golden Retriever males, highest occurrence in males neutered at <6 months, and higher still at a neutering age of 6-11 months. P values were <0.001 and equal to 0.004 respectively. This same study found the occurrence of CCLD in neutered females was significantly higher at <6m, 6-11m and 2-8 year neuter ages at $p<0.001$ to $p=0.03$ (Hart, et al., 2014). For male Labrador Retrievers being neutered at <6m old the incidence of developing CCLD increased ($p=0.02$), for their female counterpart there was a higher incidence of spayed females developing CCLD but it was not significant in that sex alone

(Hart, et al., 2014).The results of both studies conducted by Hart et. al and Riva et. al. are also homogenous to the findings in the German Shepherd breed in that neutering increases the risk of CCLD (Hart, et al., 2016). The conclusion of this study is that as the BCS was close to an ideal score that the development of joint disorders such as CCLD are in effect of the absence of gonadal hormones which delays growth plate closure in the long bone (Hart, et al., 2016).

10.2.2 Hip Dysplasia (HD)

In the same study on joint disease in Golden Retrievers a wide distinction was found in the existence of HD in early neutered males (10.3%) vs intact males (5.1%), meaning double the proportion of entire males had the disorder in comparison to early neutered males. The study found no effect on BCS in regards to occurrence of the disorder, the mean BCS of early neutered dogs with HD was 6.1 and dogs without HD was 5.7 (Riva et al., 2013). There was no significance found that early or late spaying of females elevated the occurrence of HD (Riva et al., 2013).

For comparison another study was conducted on the incidence rate of joint disorders in neutered Golden Retrievers. Significant values were found in that males neutered less than six months of age had a $p<0.001$ and at the age of 6-11 months had a $p<0.05$ in a higher rate of occurrence of HD. The same research found no significance in the development of HD in spayed Golden Retrievers vs intact females of the same breed (Hart, et al., 2014). In the same journal Labrador Retriever male dogs were found to not have any significant increase in risk of developing HD regardless of the age they were neutered. Antagonistically, female Labrador Retrievers were found to be more susceptible to HD when neutered early (<6m and 6-11m) which an increase in 2.5-3.5% ($p=0.02$) (Hart, et al., 2014).

10.2.3 Elbow Dysplasia (ED)

A study investigating the long-term health effects of neutering dogs on a sample pool of Golden Retrievers and Labrador Retrievers found that this particular joint disorder was minimal in comparison to others and no major significance was found in the occurrence of the disorder in intact males versus males neutered at an early age. There was a moderate increase in risk for male Labrador Retrievers when neutered between the ages of 2-8 years ($p=0.006$) in contrast to intact males (Hart, et al., 2014).

10.3 Racing Performance

Effect of spaying on the racing performance in female greyhounds

An observation study was completed on female greyhounds with a requirement that their oestrous cycle had never been suppressed. There were three different focus groups that were studied, they are as follows: bitches that were spayed, then started racing, bitches spayed during their racing career and finally a control group of bitches that were never neutered and ran over the same distances and times as the first two groups. The sample pool consisted of 483 female greyhounds which included 136 intact females and 347 spayed (Payne, 2013). A journal from the same researched demonstrated that performance changed between the onset of oestrous and 80-90 days post oestrous, and after this performance does not vary (Payne, 2013). Therefore entire racing performance during these time periods for entire greyhounds were not used or were excluded from the results. When the data was compiled and thoroughly analysed no significance was found that spaying had any effect on racing performance, nor were there any short or long term effects of spaying ($p<0.10$) on the racing performance of greyhounds (Payne, 2013).

10.4 Idiopathic Epilepsy

Numerous studies have been taken to discover a correlation between neutering status and idiopathic epilepsy, research does show inconsistencies in findings throughout the years. In 2011 a study of 1260 epileptic dogs in the UK were analysed from a database and paper concluded in finding neutered dogs had a higher risk in developing epilepsy (Short et al., 2011), as well as another journal examining the risk of epilepsy in neutered males and females in the US (Belanger et al., 2017). However other journals have discussed the limitations of this research as no reports were made on whether the occurrence of seizures were before or after the dogs in question were neutered (Van Meervenne et al., 2019). A recent journal published by Meervenne et al. in 2019 analysed the relationship of the dogs neutering status and the onset of seizures along with the occurrence of cluster seizures or status epilepticus. The study used a limited sample pool of 174 dogs (128 neutered and 46 intact) with idiopathic epilepsy that were found with certain keywords in their clinical records, words such as; convulsions, fits, seizures, epilepsy etc. The criteria for a dog to be determined to have an idiopathic epilepsy case were that they had two generalised seizures more than 24 hours apart. Dogs that had reactive seizures or who had had their first seizures at <6 months old or > 6 years old without an MRI or CSF sample. Using Kaplan-Meier survival curves some significant findings were noticed; intact male dogs at the onset of seizures had on average a longer survival time (1436 days) in comparison to dogs neutered before the appearance of seizures (1234 days) with a significance of $p=0.019$. (Van Meervenne et al., 2019). Similar results were found for entire vs intact females, with mean survival times of 1778.5 and 1261 days respectively and a significance of $p=0.027$ (Van Meervenne et al., 2019). Other research similar to Meervenne et al. found no significance in survival times between neuter status (Hamamoto et al., 2016, Weissl et al., 2011). All in all, there is plenty of data analysed in examining the correlation between idiopathic epilepsy and the effect of neutering status in canines worldwide, however there is a vast limitation in the research in terms of exact history of neutering and onset of seizures. This study concluded that the results given “do not support a recommendation to neuter dogs with idiopathic epilepsy as a part of an evidence-based treatment plan for idiopathic epilepsy” (Van Meervenne et al., 2019).

10.5 Urinary Tract Disorders:

Urinary Incontinence(UI)/ Urethral Sphincter Mechanism Incompetence (USMI)

USMI is the most prevailing cause of acquired urinary incontinence in spayed female dogs. With causes theorized as: “adhesion formation between the bladder neck and vaginal/uterine stump, anatomical/neural damage, hormonal changes following the removal of the ovaries” (Bleser et al., 2011).

In 2017 data was collected over the time period of 2009-2012 of healthy intact (n=163)/neutered (n=193) female dogs with USMI. The findings of the study dictated that large breed female dogs (adult weight of >25kg) have a decreased risk of developing USMI if neutered later in their first year and smaller breed dogs (<25kg) risk of acquired incontinence was not impacted regardless of age of neutering. The research did find that females with a large BCS have an increased risk of developing USMI a few years after spaying (Byron, Taylor, Philips and Stahl, 2017). A similar research initiated in 2009 used questionnaires to collect data, they used 748 owners in 37 veterinary practices with 202 cases and 168 control cases. The outcome of this investigation showed no significance between early/late spaying on the development of USMI but did however find some correlation between USMI and breeds with docked tails that was possibly due to a genetic predisposition rather than the effect of tail docking on USMI (Bleser et al., 2011). As mentioned in previous studies (Hart, et al., 2016) there was a low percentile of neutered females (<12m) developing UI (7%), with a much lower rate in females neutered at 12 months and above and not being diagnosed at all in intact females (Hart, et al., 2016).

Even more exploration was done on UI by Coit et al. which included neutered male dogs. This was research was more experimental rather than a collection of data. It stated that spayed female dogs were more susceptible to UI due to a reduction in gonadal steroids and associated hormonal changes, leading to the development of UI even after one week (Coit et al., 2008). With probable causes due to the neurological, vascular and hormonal changes rather than mechanical damage of the lower urinary tract. Coit et al. examined the effects of neutering in three areas of the bladder wall that effect function; the responsiveness to muscarinic receptors against carbachol and electrical field stimulation were explored. Both of these affect the muscarinic pathway which is responsible for emptying the bladder normally. in addition the percentage of collage in the bladder wall was inspected due to its influence on the contractability and elasticity of thee bladder which gives it its ability to relax and expand to store urine (Coit et al., 2008). Around 52 cross breed dogs of an average

age of six and weight of 24.4kg were used, the bladders were harvested and stored from the cadavers and any signs of urinary tract diseases those cadavers were excluded from the study.

Neutering had a denoting decrease in the maximum contractile response (MCR) in the smooth muscle to carbachol vs entire animals ($p < 0.01$) which also lead to a decrease in sensitivity to carbachol ($p < 0.001$), this can lead to a decrease in the strength/contractility of the bladder muscle which would increase the susceptibility to UI. MCR was lowest in the neutered female group, other investigations demonstrated no effect of gender, age or weight on the response to carbachol. The findings of the response to electrical field stimulation was a large decrease in MCR in neutered canines no matter the gender, again there was no effect of gender, age or weight on the response to the neurogenic field stimulation (Coit et al., 2008).

In terms of the change of percentage of collagen it was similar in entire dogs, with no discrepancy in neutered vs entire males. However, there was a significant increase in the collagen percentage of neutered females ($p<0.001$) in comparison to entire females and neutered males. Also found was a decline in the responsiveness to the detrusor muscle which causes a predisposition to UI in humans and therefore most likely spayed female dogs also. Furthermore it reasoned that neutered female dogs were more inclined to develop UI in comparison to neutered males as their anatomy would make it less likely, that the urethra is longer and that the passing through the penile structures enhances the urethral closure pressure which would counteract the effects of neutering on the detrusor muscle.

All of these results show that after neutering male or female dogs there is a depreciation in the response of the bladder wall to carbachol and electrical field stimulation, as well as neutered females with UI had the highest percentage of collagen and lowest response to muscarinic stimulation, understood to be the caused by the changes in reproductive hormones after an ovariectomy/ovariohysterectomy. But not to be assumed that the oestrogen removal would leave to UI as levels are low in entire males for the majority and they are continent. Therefore, perhaps a change in collagen percentage can contribute to acquired UI due to a mechanistical change as it a loss of oestrogen would not be completely responsible for a change in cladder contractability (Coit et al., 2008).

10.6 Obesity

A common perception spoken often when listing the side effects of neutering animals is the increased risk of obesity in particular female dogs. However some studies conclude perhaps more merit is put into these statements than is evidence based. Bjørnvad et al. published a journal in 2019 examined 268 healthy dogs located in Denmark, that had no illnesses and were over 2 years of age.

They examined each dog using the BCS (Body Condition Score) based on a 9 point scale, a questionnaire was required by owners to complete with inquiries such as: "dog characteristics including neuter status, owner characteristics, feeding/exercise practices, owners emotional attachment to the dog" (Bjørnvad et al., 2019). A dog denoted as heavy/obese is found to have a BCS >/= 7. Out of the 268 dogs, approximately 20.5% were located in the heavy/obese category. They had significant findings such as the BCS increased in senior bitches, decreased in senior dogs, neutering momentously increased the risk of obesity in male dogs ($p<0.001$) but not in bitches, and the risk of obesity was greater in dogs (regardless of gender) that had overweight/obese owners. Male neutered dogs were at greater risk for obesity in contrast to intact dogs ($p<0.05$), with no significant difference between spayed and intact bitches (Bjørnvad et al., 2019).

Another risk factor linked to canine obesity was in fact the owners attachment to the dog itself, feeding treats as an act of love or even out of guilt. The study showed that feeding practices of the dog was a greater threat than neutering itself, rather than attributing it to neutering status alone (Bjørnvad et al., 2019).

An alternative study was conducted in China with 2,391 healthy dogs of different breed, age, sex, neuter status, living conditions. A BCS scale of 1-5 was used with a score of 4-5 being heavy/obese (n=1062/44.4%). Multiple findings were established in relation to how often dogs were fed, the age, activity, feed type etc., that are not relevant to neuter status. In regards to neutering status they concluded that obesity was higher in females than males, with spayed females having the highest rate of obesity (Mao et al., 2013).

A less recent and quite limited study tackled the effect of neuter status on the bodyweight and metabolic rate in felines. 23 intact short-haired (12 female and 11 male between the ages of 18-24 months of age) were used, six cats of each gender were neutered and compared to five intact male and six intact cats. This study concluded that there was minimal to no effects on "serum thyroid hormone concentrations, resting or fasting metabolic rates in males or on indices of glucose tolerance", there was a significance shown ($p<0.05$) that neutered cats

gained more weight than intact cats, as well as daily food intake increased after neutering, and also spayed female cats showed a meaningful decrease in fasting metabolic rate (Fettman et al., 1995). A comparative study was done in 2013 on the association of neutering and weight gain in cats, it analysed scientific journals and came to the conclusion that neuter cats are “3.4 times more likely to be obese” than unneutered felines (Wara and Datz, 2013).

11 Behavioural Effects On Neutering Domesticated Animals

Castration of companion animals is proven to be effective in reducing behavioral problems. In male dogs such problems can be aggression towards people and territorial aggression, mounting and urine marking. Cats often have issues with spraying, roaming, and fighting. According to an article published by the Veterinary Quarterly journal, castrating these animals significantly reduces the behavioral problems mentioned above. Problems associated with cats are almost eliminated while dogs, to a lesser extent.

Although not domesticated an experiment done in 2009 on free roaming cats explored the effect of TNR on eight cat groups greater than one year old to see if neutering did reduce aggression and if so, was a reduction in cortisol responsible. As female cats tend to show aggression towards other females and young male outsiders for the purpose of this study female cats were trapped, neutered, and then returned to their original environment (Finkler and Terkel, 2010). Hair samples were collected and analysed to determine cortisol levels in these cat groups and were compared against 15 intact and 36 neutered females. Significant findings concluded that there was reduced aggression in neutered females, with also a reduced cortisol level. Similarly intact females who showed higher aggression levels had increased cortisol levels (Finkler and Terkel, 2010).

A study conducted at a referral behavioural clinic found a significance in that neutered males referred showed aggressive behaviours ($p<0.05$) and females regardless of neutering status were mostly anxious ($p<0.05$) (Cannas et al., 2017). The limitation of the studies varies in that there were no control dogs that had no behavioural issues to distinguish the cause. Many studies have confirmed that neutering status in male dogs does make a difference in aggression, with neutered males/females showing a reduction (Messam et al., 2008, Hopkins et al., 1976).

A study by Knol and Egberink-Alink performed on a group of 42 dogs, examining the effects of castration of different behavioural problems was carried out. According to the study, after castration approximately 50-70% of dogs had a rapid or gradual decline in undesirable behaviour such as mounting, urine marking and intermale aggression. However, after castration there was no change in behaviour regarding territorial and fear induced aggression. There was also no correlation between the age of dogs at the time of castration, and the rate of decline after castration. After castration, gaining weight was a common side effect of the operation, this is due to the reduction in fighting and roaming, that there is an

equal calorie intake as before the castration. Therefore, less activity with the same feeding level will increase an individual's bodyweight regardless of neuter status. The study also investigated cats, which approximately 90% of showed a rapid or gradual decline in behaviours such as spraying, roaming, and fighting with spraying having had the quickest decline after the castration (Knol and Egberink-Alink, 1989).

A likewise article publish in the journal of the American Medical Association. Here a population of 57 male dogs, who were neutered over the age of 2 years were examined. Noted behavioural issues were urine marking, mounting, roaming, fear of inanimate objects, aggression to human family members and strangers, aggression to known and unfamiliar dogs. Research showed that when neutered the feat of inanimate stimuli or aggression toward unfamiliar people did not change. Moreover, all the other problematic behaviours did reduce for urine marking, mounting, and roaming, castration resulted in an improvement of > or = 50% in > or = 60% of dogs and an improvement of > or = 90% in 25 to 40% of dogs. With both articles mentioning similar results. Castration is deemed very effective in the case reducing urine marking, mounting, and roaming, but had very little effect on aggression (Neilson et al., 1997).

12 Conclusion

From this literature review we can conclude that neutering domesticated animals in particular, canines is not a solution to the prevention of certain cancers such as testicular, prostate and mammary glands as perhaps preventing the occurrence of one possible disease increases the susceptibility to others.

In conclusion to the incidence of neoplastic development in neutered dogs the following points were found. Neutered males have a higher OR for skin tumours, tumours of the blood and haemopoietic system, tumours of the endocrine glands, the respiratory system and intrathoracic organs and unspecified locations than entire male dogs. Spayed female dogs have presented a OR for the development of skin, soft tissue tumours, tumours of the blood and haemopoietic system, the gastrointestinal tract, the oral cavity and pharynx, the respiratory system and intrathoracic organs and the urinary organs than intact female dogs.

In relation to orthopaedic disorders, large breeds in particular should not be neutered before 12-18 months old. This jeopardises the complete closure of growth plates, and can lead to other disorders such as CCLD, HD and ED. No effect on athletic ability of the bitch was deemed significant in relation to neuter status. Other research shows no requirement or valid recommendation to solve problems with neutering such as: idiopathic epilepsy, territorial behaviour, fear induced aggression. Nor did neutering cause certain diseases such as urinary incontinence, urinary sphincter mechanism incompetence or an increase in the risk of obesity.

The research dictates one major similarity, that neutering or spaying should not be advised based on one particular factor and should be carefully decided based on multiple varied elements. Another similarity across the board was a re-evaluation and subsequent agreement on the normal neutering age. Some clinics advise cats greater than 2kg regardless of age, others begin to recommend neutering appointments to owners in puppy check-ups as soon as dogs reach sexual maturity or six months of age. A mass reflection on the recommendations of veterinarians is needed, why do we influence owners on neutering their pets in terms of diseases and disorders that have little occurrence, when the complication rate is higher and even higher again is the susceptibility to development of other diseases. In 2021, neutering as a prophylactic treatment should not be advised in male dogs, and not advised in female cats or dogs at a young age.

As a general consensus based on my research I would recommend the following:

Older research dictated the best time for spaying bitches would before the first or second oestrous, recent evidence diverges from this due to all the potential affects listed above. For bitches I would recommend to wait at least one year to 18 months to spay, giving the owner all available information regarding the prevalence of pyometra and the fact that some breeds are more susceptible than others.

For male dogs I would not recommend neutering at all unless there is a real indication to do so i.e. testicular trauma, torsion, cryptorchidism. If pushed I would wait till they are approximately one year, and 18-24 months for large breeds. Clients should be aware of all the risks in choosing not to neuter i.e. testicular cancer, prostatic disorders, and how common these diseases are. Another option is to recommend an annual prostate check whilst getting vaccines. For electing to neuter I would recommend a similar discussion regarding obesity, neoplastic diseases, orthopaedic disorders etc.

For male cats I would elect to neuter; this is mainly to reduce roaming, and fighting as there are very little health risks proven in comparison to dogs. For an optimal age I would still reach for over one year, possibly less. For feral cats in order to control population over 6 months and 2kg is acceptable.

For female cats I would advise to spay to eliminate the risk of pyometra and mammary neoplasia, as the fatality rate is much higher than in canines. An optimal neutering age at six months and waiting until 11-12 months for large breed cats such as Maine Coons to ensure optimal growing time.

13 Abbreviations:

- ABP - Androgen Binding Protein
- BCS - Body Condition Score
- BPH - Benign Prostatic Hyperplasia
- CCLD - Cranial Cruciate Ligament Disease
- ED - Elbow Dysplasia
- FSH - Follicle Stimulating Hormone
- GnRH - Gonadotropin-Releasing Hormone
- HD - Hip Dysplasia
- HSA – Hemangiosarcoma
- ICT - Interstitial Cell Tumour
- LH - Luteinizing Hormone
- MCR - Maximum Contractile Response
- MCT - Mast Cell Tumour
- MTs - Mammary Tumours
- OE - Ovariectomy
- OHE - Ovariohysterectomy
- OR - Odds Ratio
- SCT - Sertoli Cell Tumour
- SEM - Seminomas
- SGP - Sulfated Glycoprotein
- TPA - Tibial Plateau Angle
- UI - Urinary Incontinence
- USMI - Urinary Sphincter Mechanism Incompetence
- UV - Ultra-Violet

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Department of Physiology and

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