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Review

Evaluating the benefits and risks of neutering dogs and cats

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Abstract

Neutering consists of removing the source of the hormones that control reproduction and determine secondary sexual characteristics. In dogs and cats, this is most commonly accomplished by castration or ovariectomy. While the primary purpose of neutering is to prevent reproduction, the procedure may have other physical and behavioural effects.

Epidemiologic research has identified many beneficial and harmful outcomes associated with neutering. A definitively causal relationship between these outcomes and neuter status cannot be accepted without consistent evidence from multiple studies of adequate size and quality. However, consideration of the possible health consequences of these associations is warranted when offering owners recommendations concerning neutering.

An evidence-based decision about neutering a particular pet requires integrating relevant research data with the veterinarian's clinical expertise and the needs and circumstances of the patient and owner. It is impossible to precisely predict the outcome of neutering for any individual. However, existing research does allow some generalization about the magnitude and clinical importance of specific risks and benefits. Overall, it appears justified to recommend spaying all females not intended for breeding, because the procedure is more likely to prevent rather than cause disease. In male dogs, the benefits of castration are not so clearly greater than the risks. The evidence is also mixed regarding the risks and benefits of neutering dogs before 5–6 months of age, and so no strong recommendation for or against the practice can be made. However, it is clear that spaying female dogs before their first heat is preferable to spaying them later.

Keywords: Cat, Dog, Castration, Spaying, Neuter, Risks, Benefits

Review Methodology: The literature was identified by keyword search of the following databases: Pubmed and Medline. Additional articles were identified by keyword search of the Veterinary Information Network and Google and by examining the references of articles identified for further relevant material. Keywords for electronic searches included the following as well as combinations and variants thereof: cat, dog, spay, castration, neuter, risk factors, risks, benefits.

Introduction

Neutering consists of removing the source of the hormones that control reproduction and that determine the typical physical and behavioural characteristics that distinguish males and females. In dogs and cats, this is most commonly accomplished by surgically removing the testicles in males (castration) and the ovaries in females (spaying), though there are a variety of surgical techniques as well as non-surgical methods of contraception to prevent reproduction without removing the source of gonadal hormones [1, 2]. There is significant variation among countries, regions and communities in specific neutering practices, in the proportion of owned cats and dogs that are neutered, and in the attitudes among pet owners and veterinarians towards neutering [3–7].

While the primary purpose of surgical neutering is to prevent reproduction, like most medical interventions, the procedure has other effects, both beneficial and undesirable. Making a rational, evidence-based decision about neutering a pet requires integrating the research evidence concerning the benefits and the risks of the procedure with the veterinarian's clinical expertise and the needs and circumstances of the individual patient and owner. Veterinarians, breeders and pet owners often have strong opinions about neutering, and unfortunately these are all too often based on tradition, habit, rumour or misconception. There is a large and complex scientific literature addressing the risks and benefits of neutering, and a number of reviews of this information have appeared in scientific publications or have been posted on the Internet by interested laypersons [8–15].

Though there are many studies that consider the impact of neutering on disease risk, they have limitations which affect the applicability of the data and conclusions they generate to individual patients. Large-scale prospective studies are rare, and even in these there are practical difficulties in controlling for confounding variables. Most of the studies which examine the possible influence of neutering on health and disease are retrospective observational studies with or without controls, and these often have significant limitations in determining the aetiological significance of the risk factors identified [16]. Many factors must be considered in evaluating the applicability of associations detected in observational studies to other populations or individual patients, including the size and composition of the study population, the study design, the appropriateness of statistical methods and the potential influence of confounding variables [17].

Another issue to consider in interpreting studies about the risks and benefits of neutering is how these risks are described. Differences between groups are often described in terms of relative risk. However, it is frequently difficult to determine from published studies the underlying absolute risk, which is critical to rational clinical risk analysis. Relative risk figures alone tend to exaggerate the perception of benefit and harm associated with risk factors [18, 19]. I have attempted, whenever possible, to provide figures for the incidence of disease conditions which may be affected by neutering, though unfortunately the true incidence of most conditions seen in veterinary medicine is not known.

In addition to the incidence of a clinical disorder associated with the neuter status, it is important to consider the clinical impact of the disorder and how amenable it is to treatment, since these factors may influence how relevant the risk of a disorder is to any decision about neutering a particular patient. This review is an attempt to consider the totality of the scientific information currently available and to draw some pragmatic conclusions about the overall benefits and risks of neutering dogs and cats.

Benefits of Neutering

Population Benefits

The primary benefit of neutering is the prevention of unintended reproduction. Though the number of unwanted cats and dogs euthanized at animal shelters in the USA has decreased from an estimated 23.4 million in 1970 to about 4.5 million by the year 2000 [20], this still represents a significant animal welfare concern. Reducing the total number of unwanted puppies and kittens remains important in reducing the relinquishment and euthanasia of these animals, and failure to neuter is an important component of the pet population problem [21, 22]. Furthermore, intact cats and dogs are at an increased risk of being given up by their owners, possibly because they exhibit unacceptable behaviours associated with being intact or because they result from unintended reproduction or are surplus offspring of other pets in the household. [23–26]. So neutering can reduce the number of unwanted puppies and kittens and the risk of owned animals being relinquished.

The feral or stray cat population, though notoriously difficult to assess, contains an estimated 30–40 million animals in the USA, most the product of unplanned breeding [20]. There is a great deal of controversy over the welfare of feral cats and the impact they may have on wildlife and public health [27–30]. It is generally agreed, however, that feral cats suffer more disease and parasitism and have shorter lives than owned cats and that reducing the number and reproduction of cats not owned is a worthwhile goal [31]. Neutering of owned and feral cats, can promote this goal, though it is likely that neutering programmes alone cannot fully control cat populations or reliably eliminate feral colonies [29, 32, 33].

While populations of stray dogs have largely been eliminated in the USA and much of Europe, such populations still exist in many countries and represent a significant human health hazard [20, 34, 35]. There are many factors involved in controlling stray dog populations and the health risk they present [34, 36]. Research suggests that neutering alone is insufficient to control stray dog populations, but it is widely considered a vital component in such efforts [34, 35, 37–39].

Risks of Reproduction

Reproduction itself has potential risks which can be eliminated by neutering. Dogs of both sexes are susceptible to infection with *Brucella canis*, a bacterium which can cause disease in dogs and humans. This bacterium can be transmitted during breeding or acquired from contact with aborted foetuses and other material from infected females. The incidence of this disease varies by country and region, from 1–18% in USA to 25% and above in some countries. Clinical symptoms other than infertility are uncommon, though some dogs experience serious infections of the bone, eyes or nervous system [31].

The most common complication of pregnancy for females is dystocia. Rates of dystocia in dogs vary greatly by breed, from as low as 5% of whelpings to over 85%

in breeds with large heads [40]. One study in Sweden, using information from an insurance database of approximately 200 000 female dogs, most of which were intact, found that 2% female dogs in the sample experienced a dystocia, and the overall incidence was 5.7 cases/1000 dog years at risk [41]. The study population consisted of dogs covered by health insurance, and so it may or may not be applicable to dogs in other countries or those whose owners do not utilize pet health insurance.

In cats, the risk of dystocia also varies by breed, with one study reporting an overall rate of 5.8% of deliveries, ranging from 0.4% in a colony of mixed breed cats to 18.2% for Devon rex cats [42].

Though dystocia can be treated medically, the majority of dogs and cats require surgical treatment [40–43]. Most females recover fully from caesarean sections, though the risks of such surgery are likely greater than those of a planned spay surgery because of the emergency nature of the procedure and the often compromised health of the female secondary to the dystocia. In breeds with a high risk for dystocia, elective caesarean section can often be performed to prevent dystocia, which is safer than emergency surgery once dystocia has developed.

Much less common risks of pregnancy, such as pregnancy toxaemia, diabetes mellitus, uterine torsion, uterine rupture and pregnancy-associated pyelonephritis can all be prevented by neutering in both dogs and cats [43].

Mammary Neoplasia

Mammary tumours are very common in intact female dogs. The chances of developing a mammary tumour increase with age and vary with breed [43, 44]. Incidence is reported in a number of different ways, which makes comparison between studies difficult. A study in Norway, where almost all female dogs are intact, found a crude incidence of malignant mammary tumours of 53.3%, with significant variation in risk by breed and age [45]. A study in the UK, looking at a population of both intact and spayed dogs in a health insurance database, found mammary tumours to be the second most common type of tumour, with an age standardized incidence of 205 tumour per 100 000 dogs per year; however, no breakdown of this figure according to the neuter status was reported [46]. A Swedish study found an incidence in intact females of 1% at 6 years of age, 6% at 8 years and 13% at 10 years (when the study was terminated) [47]. The incidence of mammary tumours in female cats is roughly half that seen in dogs, and there is no apparent protective effect of having a litter for dogs or cats [44, 48]. Mammary neoplasia is extremely rare in male dogs [44].

About half of the canine mammary tumours are malignant, whereas 85–90% of the feline mammary tumours are malignant [44, 49]. Mammary cancer is usually treated surgically, often with adjunctive post-surgical chemotherapy, and it is often fatal despite treatment, with 59% dogs with malignant tumours in one study eventually dying of causes related to their cancer [50].

Spaying dramatically reduces the risk of mammary tumours in both dogs and cats. In dogs the risk has been reported as 0.5% for females spayed before the first oestrus, 8% for those spayed before the second oestrus and 26% for those spayed after the second oestrus [51]. One study in cats found those spayed prior to 6 months of age had a 91% reduction in mammary cancer risk, and the risk was reduced by 86% in those spayed before 1 year [48]. Spaying dogs later than the third oestrus does not reduce the risk of developing mammary cancer, but spaying at the time of surgical removal of the mammary tumour or within 2 years before the diagnosis of mammary cancer is associated with longer survival [50].

Pyometra

Pyometra is a bacterial infection of the uterus that occurs as a consequence of changes in the uterine environment brought about by repeated oestrus cycles [43]. Pyometra can be treated medically, with resolution of infection reported in 46–95% cases, with minimal short-term complications, and with relatively high rates of recurrence (20–28%) and subsequent fertility problems [52–58]. It is more commonly treated, and recurrence prevented, by spaying the affected dog [43, 55].

A study in Sweden, where elective spaying is rarely practiced, found that overall 25% of the females in the study developed pyometra by 10 years of age, and it was expected the risk would continue to increase in even older females. The risk varied considerably by breed, with some breeds having a 10% rate of pyometra and others up to 50%. Risk increased with age for all breeds [59]. Pyometra has been reported in cats, but no published figures regarding the incidence are available.

Mortality from pyometra treated surgically is variable, from 4.2 to 17% in dogs and 8% in cats [43]. Mortality rates associated with medical treatment of pyometra were not identified. However, such treatment would not be appropriate for critically ill patients, and so the mortality rate would be expected to be lower for medically treated cases since significantly compromised individuals would likely be treated surgically.

Spaying essentially eliminates the risk of pyometra in dogs and cats. Uterine stump pyometras do occur if some ovarian tissue or other source of progesterone is present, but this is rare [43]. Ovariectomy is as effective as ovariohysterectomy in preventing pyometra [60].

Neoplasia of Reproductive Organs

Tumours of the ovaries are uncommon in dogs and cats with reported incidences of 6.25% in dogs and between

0.7 and 3.6% in cats. There are several different types of ovarian tumours with variable degrees of malignancy. Little reliable information exists regarding the mortality associated with these tumours [61].

Uterine tumours are very rare in dogs and cats, accounting for less than 2% of feline tumours and less than 0.5% of all canine tumours. Tumours of the uterus can generally be successfully removed by spaying the animal, though recurrence and spread to other organs have been reported [61].

Tumours of the vulva or vagina in female dogs are not common, though they represent 2–3% of all canine tumours. They occur primarily in intact females and often have receptors for ovarian hormones, and they are less likely to recur in dogs spayed at the time of tumour removal [61–64]. This suggests that the risk of such tumours is decreased in spayed females. Most vulvar and vaginal tumours are benign and can be cured by surgical removal, though the minority that are malignant have a poor prognosis and often recur or metastasize [61].

Various rates of occurrence have been reported for testicular tumours, but random samples of testicles from dogs autopsied for reasons not related to testicular disease have shown that 16–27% dogs had tumours, and many of these had more than one [65]. The testicles are the second most common site for cancer in intact male dogs [66]. Cryptorchid testicles are more likely to develop tumours, especially in dogs under 10 years of age [67, 68].

There are several types of testicular tumours. Most are slow to metastasize, with less than 15% affected dogs showing spread to other organs. Some testicular tumours produce hormones, including oestrogen which can cause feminization and bone marrow hypoplasia. Castration is the treatment of choice for testicular neoplasia, and it is usually curative [43, 61].

Prostate Disease

The most common disease of the canine prostate is benign prostatic hyperplasia (BPH) [43, 69]. The incidence of this disorder increases with age, from 15–40% for dogs under 7 years of age to 60–100% for dogs over 7 years of age [69–71]. While most dogs have a few symptoms from BPH, some experience difficulty urinating or defecating or have bloody preputial secretions. BPH is a predisposing and complicating factor for prostatitis [43]. Prostatitis has been reported to occur in up to 28.5% intact male dogs [69, 72]. It is a serious and uncomfortable disease, though rarely life-threatening. Both BPH and prostatitis are rare in neutered dogs and both are effectively prevented and treated by castration [43, 69].

Behavioural Benefits

Behavioural problems are an important reason for relinquishment of pet dogs and cats by owners [20, 27, 73]. The most common problem behaviours include aggression towards people or other animals, inappropriate elimination and fearful behaviours [74]. To the extent that neutering increases or reduces the risks for these behaviours it can have an important impact on the relationship between pet and owner and ultimately on the pet's survival.

The biological and environmental influences on animal behaviour are complex and difficult to unravel, so epidemiological correlations are unreliable in predicting the outcome of interventions in individual cases. Most of the literature concerning neutering and behaviour is consistent of owner surveys or analyses of biting or other problem behaviours reported to animal control agencies or shelters. These studies have significant methodological limitations as they are generally observational and retrospective, and often involve sample populations that may not be truly representative of dogs and cats generally. However, there are some consistent patterns that emerge from studies on normal and problem behaviours in dogs and cats which illustrate the potential behavioural benefits and risks associated with neutering.

Most studies have found intact male dogs to be disproportionately involved in aggressive behaviour [75–77]. Others have reported marked reductions in aggression and other problem behaviours in male dogs as an effect of castration. In one study, roaming behaviour decreased 90%, aggression between males decreased 62%, urine marking decreased 50% and mounting decreased 80% following castration [78], and several other studies have found similar results [79–81]. Some studies have also reported intact dogs to be more likely to bite humans than neutered animals [77].

Castration also dramatically reduces fighting, urine spraying and roaming in male cats [81–83]. One of the few experimental, prospective studies in this area compared various physical and behavioural characteristics of kittens neutered at 7 weeks of age, others neutered at 7 months of age and a control group left intact. This study found intact cats to be more aggressive towards other cats and less affectionate towards humans than neutered cats [84].

Miscellaneous Benefits

Almost every veterinary epidemiologic study of any disease examines differences in incidence between males and females and intact and neutered animals. If a significant correlation is found, this may or may not have meaningful clinical implications. There are likely many more such associations reported than are listed here, but these are some that have clear significance when considering whether or not to neuter and about which pet owners often have questions and concerns.

Perineal hernias are uncommon in dogs, but no precise incidence has been reported. In one study, 93% of the cases were intact males, and an association with prostatic disease and prostatic hormones is suspected, and so neutering is likely to be protective for this disorder [85, 86]. Perineal hernias can be repaired surgically, with a recurrence reported in from 20 to 40% patients. Castration at the time of initial repair is often recommended, because it may reduce the rate of recurrence, especially in dogs with concurrent prostatic disease [87, 88].

Perianal fistulas is an immune-mediated disease seen most commonly in German Shepherds and Irish Setters and rarely in other breeds. It occurs predominantly in intact male dogs, which suggests a hormonal influence though a specific causal connection has not been identified. In one study, males outnumbered females 2:1 and intact dogs were 86% of the affected patients [89]. Perianal fistulas are chronic and often cause significant discomfort. A variety of medical and surgical treatments are used, with reports of long-term resolution of the condition in from 30 to 78% of cases [90–92].

There is some suggestion in research on laboratory animals as well as retrospective epidemiologic studies of dogs and cats that neutered animals may live longer than intact animals, though the effect is not large or consistent across studies [93–99]. There has been one retrospective survey study of Rottweiler dogs which found an association between the length of time females remained intact and their odds of achieving exceptional longevity (defined as a lifespan $\geq$13 years) [100]. However, a previous survey study from the same population reported that intact females lived on an average for 7.5 years, compared with 9.8 years for spayed females [101]. The implications of these studies for other breeds or for any general relationship between lifespan and neuter status are not clear. Also, the possible effects of differences in the care neutered and intact animals receive, genetic factors and many other variables have not been evaluated, which complicates any interpretation of differences in longevity. Therefore, no firm conclusions can be drawn about the effect of neutering on longevity.

Risks of Neutering

Surgical Risks

Like all surgeries, neutering involves some risk of perioperative complications. Total complication rates for routine castration or spaying have been reported from 2.6% to 20% of the cases [102–105]. The majority of these are minor and require no treatment [102, 105]. Complication rates vary considerably from practice to practice and are generally reported to be higher in studies of surgeries performed by students in training [102, 105]. Reported death rates are less than 0.1% [102].

Neoplasia

Prostate cancer in dogs has previously been reported to have an incidence of less than 1% [43], but several recent studies have suggested it may be more common, though not always clinically recognized, and these papers have reported rates of 3.6–13% [69, 72]. Most such cancers are malignant, with metastases reported in 40–80% of the cases at the time of diagnosis [43, 106]. There is some uncertainty about the role of castration in prostate cancer development. All the studies have been retrospective epidemiologic surveys of a relatively small number of dogs with prostatic carcinoma (n=7–76). Some have found fewer prostate cancers in castrated dogs than in intact dogs [106–108]. However, others have found either no effect of castration on the rate of prostate cancers [109] or an increased risk for castrated dogs [72, 110]. Canine prostatic adenocarcinomas arise predominantly from androgen-independent ductal epithelial cells, and so it appears that, unlike in humans, androgens are not responsible for the initiation or progression of prostatic cancers. However, it is unclear whether, overall, castration is beneficial, neutral or a risk factor for the development of prostate cancer [67, 110]. Prostate cancer is an aggressive cancer with a poor long-term prognosis [67].

Osteosarcoma is a bone tumour usually seen in large breed dogs [111, 112]. The overall incidence has been reported as 0.2%, but for at-risk breeds rates of 4.4–6.2% are often reported [8, 113]. A rate of 12.5% was reported in one study of Rottweilers, though the authors suggested this might have been an overestimate [101]. Neutered dogs have been reported to be at higher risk for osteosarcoma than intact dogs [101, 111]. In the study of Rottweilers, no difference was found in the overall risk for intact versus neutered animals of either sex, but neutering before 1 year of age was found to increase the risk, and it was found that the longer an individual had been intact the lower their osteosarcoma risk [101]. However, the neutered animals in this study (especially the spayed females) lived longer than the intact animals, which may have contributed to an increased incidence of cancer in the neutered group.

It is possible that neutering, especially before sexual maturity, raises the risk of osteosarcoma, at least in predisposed breeds. Osteosarcoma is an aggressive cancer with a poor long-term prognosis, and it is generally treated with surgery and chemotherapy [112].

Hemangiosarcoma is a malignant neoplasm of vascular endothelial cells [114]. The true incidence has not been reported, but it makes up 5% of all non-skin cancers in dogs [114]. It is less common in the cat, found in 0.5% cats autopsied and 2% of cancers in this species [114]. It most commonly originates in the spleen, and certain breeds (such as German Shepherds, Labrador Retrievers and Golden Retrievers) are at greater risk than others [114–116]. Primary cardiac hemangiosarcoma may also occur, with a reported incidence of 0.19% [117].

In dogs, spayed females have been reported to have 2 times the risk of splenic hemangiosarcoma and 5 times the risk of cardiac hemangiosarcoma compared with intact females [115, 117]. Castrated males have been found to have no increased risk of splenic hemangiosarcoma [115] and only a slightly higher risk than that of intact males for cardiac hemangiosarcoma [117]. Hemangiosarcoma is an aggressive cancer with a poor long-term prognosis, and it is usually treated by splenectomy (if this is the primary site) and chemotherapy [114].

Transitional cell carcinoma is a cancer of the lower urinary tract, usually found in the bladder and uncommonly in the urethra of dogs [118]. It represents 1–2% of canine cancers and is rare in the cat [118, 119]. It is more common in females than males, prevalence varies by breed, and neutered animals have been reported to be at 2–4 times greater risk than intact animals [119, 120]. Transitional cell carcinoma is an aggressive cancer with a fair long-term prognosis, and it is usually treated with chemotherapy and sometimes surgery or radiation therapy [118].

Orthopaedic Disease Risk

Rupture of the cranial cruciate ligament in the stifle is a common problem of large and giant breed dogs, with an overall incidence of 1.8–4.5%, though the incidence in predisposed breeds has been reported to be as high as 8.9% [121–124]. In addition to breed and obesity, neutering increases the risk of cranial cruciate ligament rupture [121–124]. One retrospective case control study found that in dogs affected by cranial cruciate ligament disease, those neutered before 6 months of age were more likely to have an excessive tibial plateau angle than those neutered later [125]. Cruciate ligament rupture is treated with a variety of surgical approaches, and it has an excellent long-term prognosis [126, 127].

Hip dysplasia is a developmental abnormality of the hip joint that can result in arthritis and clinical discomfort. It is rare in small breeds, with less than 1% of the dogs affected, but it can be seen in as many as 40–75% of large breed dogs [124, 128–130]. Hip dysplasia is estimated to lead to clinically significant arthritis is less than 5% of the affected dogs, but there are many factors involved including breed, weight and the degree of anatomic abnormality of the hip joint, which makes predicting the outcome for any individual difficult [130]. The incidence of hip dysplasia is most strongly associated with breed and family history [124, 131, 132].

Some studies have identified neutering as increasing the risk of hip dysplasia [124, 133]. The age at neutering may also be a factor influencing the development of hip dysplasia [9]. It is unclear if the increased risk is directly the result of the effects of neutering or of an increased incidence of obesity in neutered dogs.

Hip dysplasia can be treated if detected early with surgical therapies that reduce the chances of clinically significant arthritis later in life [134, 135]. In older dogs that have already developed arthritis and clinical symptoms, these can be managed surgically or medically, with medications, weight reduction and other therapies [136–138]. Because of the genetic basis of the disorder, the ideal approach to eliminating it is to neuter those dogs that carry the predisposing genes, if they can be identified prior to breeding [139, 140].

A number of studies have found a large majority of spontaneous femoral capital physeal fractures in cats occur in obese neutered males [141–144]. It is clear that neutering delays closure of the growth plates in male cats [145], and so it may be an independent risk factor for such fractures, though neutering also increases the incidence of obesity, and the relative contribution of obesity and neutering to the risk of these fractures has not been elucidated.

Behavioural Risks

Though neutering has generally been associated with a decreased incidence of some kinds of aggression, there is also limited evidence that it may be associated with an increase in some aggressive behaviour. A number of studies of dogs referred for treatment of behaviour problems have identified a higher proportion of spayed than intact females among animals exhibiting aggression [75, 77]. Another study, in which breed club members were surveyed and an open-access web-based owner survey was conducted, found more aggression towards humans and other dogs in spayed than intact females [146]. However, without matched control groups or information about the ratio of intact and neutered male and female dogs in the general populations from which the study subjects were drawn, it is not possible to definitively assess if neutering is associated with more aggression in females, or whether any such association might be causal.

Another study found that if female dogs under 6 months of age showed human-directed aggression prior to being spayed, this aggression became worse after ovariohysterectomy, though aggressive behaviours were not observed in those females who were spayed and had not shown aggressive tendencies prior to the procedure [147]. However, there were differences between the control group and the spayed dogs in addition to having surgery, which make it difficult to generalize from these results.

One survey of Springer Spaniel owners identified more owner-directed aggression reported in dogs that were neutered than in intact dogs [148]. How reliable such an owner survey might be or how applicable to other breeds, is unclear.

One study found female German Shepherds who were neutered were more reactive to the presence of unfamiliar humans and dogs than were intact dogs [149]. Another study found neutered dogs to be more active than intact dogs and castrated males to be more excitable than intact males, but found no other measurable behavioural differences between the groups [150]. The clinical significance or applicability of these findings to behaviour problems is unclear.

One study has examined the relationship between neutering and the development of age-related behavioural changes thought to be similar to Alzheimer's disease or other forms of senile dementia in humans [151]. Such changes are relatively common, being reported in 28% of dogs at 10–12 years old and 68% of dogs at 15–16 years old [152]. When multiple comparisons were made between intact males, castrated males and spayed females (no intact females were included in the study), the only association found was that when castrated male and spayed female dogs were combined and compared with sexually intact males, the percentage of intact males that progressed from mild to severe cognitive impairment was significantly lower than the percentage of neutered dogs that progressed [152]. It is unlikely that this limited finding has great significance in terms of the overall risk for the development of cognitive dysfunction in neutered or intact dogs.

Miscellaneous Risks

Urinary incontinence is common in middle-aged to older spayed female dogs, with a reported incidence of 5–30%. Rates are lower in small dogs and higher in large breed dogs [9, 153–156]. Medical treatment is reported to successfully control the symptoms in 65–75% dogs [153, 157, 158].

Two retrospective reports, one of dogs with persistent urinary tract infections and one very large study of nearly 11 000 dogs with uroliths removed and submitted to a university laboratory for analysis, found spayed females to be at an increased risk for urinary tract infections compared with intact females [159, 160]. However, one case-control study of 78 dogs with naturally acquired urinary tract infections did not find such a relationship [161]. No association with urinary tract infections has been found for the neutering of male dogs [159]. The majority of uncomplicated urinary tract infections can be successfully resolved with antibiotic treatment.

Feline Lower Urinary Tract Disease (FLUTD) is a collection of symptoms ranging from mild haematuria and stranguria to potential life-threatening urinary tract obstruction [162]. Causes include idiopathic interstitial cystitis, urinary tract infection, urolithiasis and neoplasia [162]. FLUTD has been reported to occur in 1.3–4.6% cats in private practice and 7–8% cats in veterinary teaching hospitals [3, 163]. While some studies have found no association between FLUTD conditions and neutering [8, 164], and it does not appear that neutering affects the size of the urethra in male cats (a possible risk factor for obstruction) [165], several epidemiologic studies have found that neutering status does raise the risk of some causes of FLUTD [166, 167]. Castrated males were at an increased risk compared with intact males for all causes of FLUTD except for infection and urinary incontinence. Spayed females had an increased risk for urolithiasis, urinary tract infections and urinary tract tumours, but not other causes of FLUTD. Intact females had a decreased risk for most causes [167]. While most cases of FLUTD are treatable and not life-threatening, urinary tract obstruction in males is a very serious condition. This occurred in about 12% cats with FLUTD symptoms, and the risk is higher in castrated male cats [167, 168].

Hypothyroidism is usually due to autoimmune thyroiditis or idiopathic thyroid atrophy [169, 170]. It occurs in an estimated 0.2–0.3% dogs [171, 172]. An epidemiologic survey of 3206 dogs diagnosed with hypothyroidism at veterinary teaching hospitals, and a much smaller study of 66 dogs with hypothyroidism confirmed by thryotropin stimulation testing, both found that neutered dogs are at higher risk than intact dogs for developing hypothyroidism [171, 172]. However, one study of 136 dogs referred to a veterinary teaching hospital for suspected hypothyroidism found no difference in neuter status between those confirmed by thyrotropin stimulation testing to be hypothyroid and those in which the diagnoses was excluded [173]. Supplementation of thyroid hormone resolves the disease symptoms in most cases [172, 174].

Diabetes mellitus is a multifactorial disease that has a variety of manifestations and sequelae. Incidence in cats has been reported from 0.08 to 2%, with Burmese cats having a higher rate of occurrence than other breeds or mixed-breed cats [175–178]. Incidence in dogs is estimated at 0.19–0.64%, with significant breed variations [179, 180]. Diabetes is more common in male cats than females, and neutering is associated with an increased risk of diabetes in both male and female cats in some studies [176]. However, when age and weight are controlled for no effect of neutering is seen in other studies [178]. In dogs, diabetes is often reported to be more common in females than males [180, 181] though this is not found in all populations [177].

Castrated males were at a higher risk for diabetes than intact males in one study, though weight was not controlled for [182]. Some authors have suggested that intact females may be at a greater risk of diabetes because of the antagonistic effects of ovarian hormones on insulin, and spaying is an important part of regulating diabetes in female dogs [177]. Obesity is clearly a risk factor for diabetes in cats, though there is some debate about whether this is true in dogs, and since neutered animals are prone to be heavier than intact animals matched by breed and age, this may be a confounding factor creating the appearance of a direct effect of neutering on diabetes risk [175–177, 180, 181]. Diabetes is a serious chronic disease that can often be managed for long periods but cannot be cured.

Pancreatitis can manifest as a chronic or acute disease with varying degrees of severity and multifactorial causation [183]. The true incidence of pancreatitis is unknown, and although autopsy surveys have found evidence of inflammation in anywhere from less than 1% to more than 50% of dog pancreases, no study has reported the true incidence of clinical pancreatitis [184–186]. In dogs, there is some evidence that neutered animals may be at higher risk than intact animals for acute pancreatitis [187, 188].

Obesity is a common and growing clinical problem in dogs and cats. Though clear and consistent definitions do not exist, various reports have suggested that among dogs 18–44% are overweight and 2.9–7.6% are obese [189–191]. Among cats, an estimated 19–40% are overweight and 7.8% are obese [192–194]. Being overweight is a significant risk factor for many serious diseases [178, 195–197]. Almost all studies agree that neutered cats and dogs are more likely to be overweight or obese than intact cats and dogs [189–191, 193–195, 198–204]. However, the exact relationship between neutering and excess body weight has not been clearly established.

Some studies have indicated that neutered animals have a lower metabolic rate [205–208]. But other studies, which control for the proportion of lean body mass and fat in subjects, have found comparable metabolic rates in intact and neutered animals [202–204, 209]. There is evidence that neutered animals may gain excess weight because they eat more and expend less energy than intact animals despite having the same resting metabolic rate [83, 200, 204, 206, 207]. There are also many other risk factors for obesity, including sex, breed and variables associated with owners and their habits, that affect the chances of an animal becoming overweight regardless of whether it is neutered or intact [189, 194, 195, 210].

It is clear that obesity is preventable. Proper restriction of total calorie intake is all that is necessary to prevent obesity regardless of neuter status [189, 195].

Optimal Age for Neutering

For decades, the traditional age for neutering dogs and cats in the USA has been 6–9 months. There is no clear scientific basis for choosing this age, and it has been suggested that the practice arose as a response to anaesthetic mortality in younger animals in the first half of the twentieth century [8]. Anaesthetic procedures have evolved dramatically since that time, and it has since been demonstrated that not only is the procedure safe in puppies and kittens 7–12 weeks of age, but these younger patients actually recover faster and have fewer complications than those neutered at the traditional age [84, 103, 211].

One large-scale (775 cats and 1213 dogs) trial found no significant differences in the week immediately after surgery between cats and dogs neutered at the traditional age and earlier, apart from more minor surgical complications in the traditional age group [103]. Another study followed 31 kittens neutered at 7 weeks and at 7 months for 1 year and found no differences in any measures of behavioural or physical development [84]. Two large retrospective cohort studies followed puppies (n=269) and kittens (n=263) adopted from shelters and neutered before or after 24 weeks of age for approximately 3 years [212, 213]. Of the numerous measures of health, behaviour and relationship with owner examined in cats, the only difference detected was a greater incidence of urinary tract problems in the cats neutered at the traditional age [212]. In the canine study, puppies neutered earlier than 24 weeks did have a higher rate of infections, primarily parvovirus. This may have been due to differences in the management policies of the two shelters in which the subjects were neutered, since the rate of parvovirus infections was higher at the shelter where most of the early neutered animals were spayed or castrated [213]. Dogs in the traditional-neuter age group had more gastrointestinal problems than dogs in the early neutered group [213]. Interestingly, there was no difference in the incidence of urinary incontinence in female dogs in this study, which contrasts with an owner survey study of 206 dogs that found urinary incontinence occurred twice as often in females spayed after their first heat as those spayed before having a heat cycle [156].

A different group of researchers reported two very similar retrospective cohort studies following over 1800 dogs and 1600 cats adopted from shelters after being neutered (either before or after 5.5 months of age) for an average of 4–4.5 years, but as long as 11 years in some cases, and examined numerous behavioural and medical outcomes [9, 11]. For dogs, 7 out of 14 behavioural measures appeared affected by age at neutering, with early neutering worsening 3 problem behaviours and improving 4. Animals in the early neutered group exhibited higher rates of noise phobia and sexual behaviours. The early neutered group also exhibited less separation anxiety, fearful urination in the house and escaping. Early castrated males (but not spayed females) showed more aggression towards humans in the household and more barking. When only problems considered by owners to be serious were analysed, the reduced risk of escaping for the early neutered group was the only behaviour still significantly associated with age at neutering [9].

Of the medical conditions monitored, four were significantly associated with age at neutering. Dogs neutered early had higher rates of hip dysplasia, though the dysplasia seen in the traditional-age group was clinically worse and this group was far more likely to be euthanized for the problem than the early neutered group. Rates of cystitis and urinary incontinence were higher for females neutered before 5.5 months of age. The early neutered group had lower rates of respiratory infections but higher rates of parvoviral infection. And finally, the early

Table 1 Effects of spaying on females. See text for more detail on incidence and clinical significance of specific conditions

Condition	How common?	How serious?	Effect of spaying	Species affected	Comments
Unwanted litters	Very common	Very	Prevents	Dog and cat	Significant pet overpopulation and associated euthanasia
Risks of reproduction	Uncommon	Variable	Prevents	Dog and cat	Dystocia, brucellosis, diabetes, others; risk of dystocia can be high for certain breeds
Mammary neoplasia	Very common	Very	↓Dramatically	Dog and cat	Generally poor prognosis
Pyometra	Very common	Very	Prevents	Dog and cat	
Uterine neoplasia	Rare	Variable	Prevents	Dog and cat	Some benign/removable, some malignant
Ovarian neoplasia	Uncommon	Variable	Prevents	Dog and cat	
Vaginal/Vulvar neoplasia dog	Uncommon	Moderate	↓Dramatically		
Osteosarcoma	Uncommon	Very	Possibly ↑	Dog	Rare in most breeds, common in a few breeds
Haemangiosarcoma	Uncommon	Very	↑	Dog	Rare in most breeds, common in a few breeds
Transitional cell carcinoma	Uncommon	Very	↑	Dog	Incidence varies by breed
Cruciate ligament disease	Common	Moderate	↑	Dog	Incidence varies by breed, surgically treatable
Hip dysplasia	Common	Variable	Probably ↑	Dog	Rare in most breeds, common in a few breeds
Aggressive behaviour	Common	Very	Possibly ↑	Dog and cat	
Urinary incontinence	Very common	Mild	↑	Dog	Medically controllable in 65–75% of cases
Urinary tract infection	Common	Moderate	Possibly ↑	Dog	Easily treatable in most cases
Hypothyroidism	Uncommon	Moderate	Possibly ↑	Dog	Easily treatable
Diabetes mellitus	Uncommon	Very	Possibly ↑	Dog and cat	Incidence varies by breed
Acute pancreatitis	Uncommon	Very	Possibly ↑	Dog	
Obesity	Common	Very	↑	Dog and cat	Easily prevented by calorie restriction
Longevity	–	–	Possibly ↑	Dog and cat	Spayed females may live longer than intact females

↓=decreases/reduces, ↑=increase/exacerbates.

neutered group had a lower rate of obesity than those dogs neutered at the traditional age. The remaining 43 outcome measures studied showed no difference between the two groups [9].

In the feline study, early neutering increased shyness around strangers for both sexes, and it increased hiding behaviour for males but not females. Early neutered cats showed less hyperactivity, and early neutered males showed less aggression towards veterinarians, less urine spraying and fewer sexual behaviours. There may also have been a decreased rate of scratching furniture in early neutered cats, but these cats were more likely to have been declawed, so the effect may be an artefact. When only problems considered serious were analysed, none of these behaviours was significantly associated with age at the neuter status [11].

Early neutered cats experienced lower rates of asthma and gingivitis, and males experienced fewer abscesses in the first 5–6 years after neutering. Cats neutered early may have experienced lower rates of cancer, but when only malignancies confirmed by a veterinarian were considered this effect was not significant. For the other 38 outcome measures studied, no difference between the groups was observed [11].

Considering the very large number of medical and behavioural conditions examined in the four retrospective studies of shelter animals, a few statistically significant associations were found. It is likely that with so many variables compared between groups some of these associations are spurious, and firm conclusions about a causal relationship between age at neuter and any given medical or behavioural conditions should not be made without a plausible biological mechanism and corroborating information from other studies. There were some differences in the specific associations identified by the two research groups. Despite similar methodologies and source populations, it is possible that these differences reflect true differences in the populations studied or the evaluation methods. However, if some of the associations identified are because of Type-I error, it would be expected that different studies would identify different spurious associations. Consistency between studies in identifying specific associations would strengthen the hypothesis that such associations are truly causal.

Table 2 Effects of castration on males. See text for more detail on incidence and clinical significance of specific conditions

Condition	How common?	How serious?	Effect of castration	Species affected	Comments
Unwanted litters	Very common	Very	Prevents	Dog and cat	Significant pet overpopulation and associated euthanasia
Testicular neoplasia	Uncommon	Moderate	Prevents	Dog	Most benign and surgically removable
Prostate disease	Very common	Variable	↓Dramatically	Dog	Some have few symptoms others have severe, chronic disease
Behaviour problems	Common	Variable	Variable	Dog and cat	Conflicting studies; most report less aggression, roaming, urine marking
Perineal hernias	Uncommon	Moderate	↓	Dog	Can often be repaired surgically
Perianal fistulas	Uncommon	Moderate	↓	Dog	Incidence varies by breed, some respond well to treatment others are serious chronic problem
Prostatic neoplasia	Uncommon	Very	Probably ↑	Dog	Poor prognosis
Osteosarcoma	Uncommon	Very	Possibly ↑	Dog	Rare in most breeds, common in a few breeds
Haemangiosarcoma	Uncommon	Very	↑	Dog	Rare in most breeds, common in a few breeds
Cruciate ligament disease	Common	Moderate	↑	Dog	Incidence varies by breed, surgically treatable
Hip dysplasia	Common	Variable	Probably ↑	Dog	Rare in most breeds, common in a few breeds
Femoral physeal fracture	Uncommon	Moderate	Possibly ↑	Cat	Obesity may be confounding factor
Hypothyroidism	Uncommon	Moderate	Possibly ↑	Dog	Easily treatable
Diabetes mellitus	Uncommon	Very	Possibly ↑	Dog and cat	Incidence varies by breed
Acute pancreatitis	Uncommon	Very	Possibly ↑	Dog	
Obesity	Common	Very	↑	Dog and cat	Easily prevented by calorie restriction
Longevity	–	–	Possibly ↑	Dog and cat	Castrated males may live longer than intact males

↓=decreases/reduces, ↑=increase/exacerbates.

Conclusions

It is apparent that spaying and castration have benefits for the pet population in general and both benefits and risks for individual dogs and cats. It is impossible to predict the precise outcome of neutering for any individual given the numerous and interacting aetiological factors involved in most serious behavioural and medical conditions. Any decision to neuter a particular pet must include consideration of individual circumstances and the values and goals of the owner as well as the risks and benefits identified by epidemiologic data. However, these research data do allow some cautious generalization about the magnitude and clinical importance of specific risks and benefits associated with neutering.

In females, spaying reduces or eliminates the risk of several common, serious disorders, including mammary neoplasia and pyometra, and eliminates the inconvenience and risk associated with oestrus and reproduction for both cats and dogs. It appears to increase the risk of a number of medical and behavioural conditions; however, many of these are either relatively uncommon or easily treated, and the absolute risk often varies markedly by breed. When the totality of the scientific evidence is considered, it appears justified to recommend spaying for most females not intended for breeding, because the procedure is more likely to prevent rather than cause disease. Table 1 summarizes the effects of spaying on females. Because the evidence is complex, such a shorthand summary can be a useful reference; however, it is necessarily an oversimplified representation that cannot convey the full complexity and ambiguity of the data.

In male dogs, the individual benefits of castration are not so clearly greater than the risks as they are for females. Males may be more likely to benefit than to be harmed by castration, but the balance of the evidence is close. The population benefits, of course, argue in favour of routine neutering of male dogs. For male cats, however, neutering confers more benefit than harm. Table 2 summarizes the effects of castration on males. Again, this is intended only as a convenient reference to the more detailed, nuanced information presented in the text.

The evidence is mixed regarding the risks and benefits of neutering dogs before 5–6 months of age, and so no strong recommendation for or against the practice can be made. The lack of clear and consistent associations between age at neutering and particular medical or behavioural outcomes despite several large studies suggests that there are unlikely to be many effects of great clinical significance for dogs or cats in general that are attributable to age at neutering. However, it is clear that spaying female dogs before their first heat is preferable to spaying them after this event, primarily because of the impact on the risk of mammary neoplasia.

There are many areas in which a greater quantity and quality of data would aid in evaluating the significance of specific risk and benefits associated with neutering. Establishing the true prevalence of many conditions potentially affected by neutering would be helpful in evaluating the importance of the effects of neutering on the relative risk of these conditions. Establishing that associations between neuter status and specific outcomes are truly causal, by confirming such associations in multiple studies of adequate size and quality, by investigating putative underling biologic mechanisms and by conducting experimental studies where feasible, would make it possible to know if these associations are truly relevant when making recommendations concerning neutering. And the clinical significance of these associations must be considered. Common and serious conditions prevented or caused by neutering clearly have more clinical importance than rare and minor or easily treated conditions. Finally, this information must be made available in a clear and accessible form to veterinarians and, through them, to pet owners.

It is critical to integrate relevant research evidence with the unique circumstances of each pet and owner when making recommendations concerning neutering. The evidence is complex and often inconclusive, so unambiguous predictions about outcomes for individual patients are rarely justified. There is, unfortunately, a tendency for lay people and veterinarians alike to react to the complexity and uncertainty of the research data by making broad generalizations or by sticking to habit and tradition. However, our pets are better served by a judicious and thoughtful evaluation of the quality and significance of existing and new data in the light of individual circumstances and the characteristics of each animal.

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