**Perioperative Care of Dogs Undergoing Adrenalectomy**

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**INTRODUCTION**

To ensure successful outcome in complicated surgical patients, such as patients undergoing adrenalectomy, the complete medical path from start to finish has to be optimised. Prior planning and preparation are essential prerequisites for optimisation of the perioperative care. Successful outcome for all patients, including those at high risk of experiencing serious complications, should involve a team of multi-disciplinary experts (internist, anaesthetist, diagnostic imager, surgeon, and critical care specialist). Over time, the consensus on general guidelines for treatment can be documented in a protocol to improve and support communication and planning.

The management of patients undergoing adrenalectomy is organised around three aspects: the general physical and medical condition of the patient, general considerations related to the adrenal tumour(s) and the surgical removal, and aspects that are the consequences of hormonal imbalance caused by the tumour and its removal.

**GENERAL CONSIDERATIONS**

Most patients with adrenal tumours are middle-aged or old and often have concomitant age-related health problems. These should be assessed and managed prior to surgical intervention, as they have major impact on final outcome. Information on uni- or bilateral involvement, the size of the tumour, and biological behaviour including blood vessel involvement, and presence of metastases help to determine the best surgical approach and prognosis.\(^1,2\)

The historically most applied surgical approaches to adrenalectomy are ventral midline coeliotomy (with paracostal extension) and the paracostal approach. In human medicine, laparoscopy has become the standard in adrenalectomy, and it has now also been introduced in veterinary medicine. Laparoscopy may decrease the incidence of several postsurgical complications.\(^3,4\)

General care considerations should surround any surgical intervention such as fluid therapy, pain management, monitoring, nursing care, and hygiene. Perioperative fluid therapy should be guided by the patient's fluid balance, any perioperative blood loss, use of combined general and loco-regional anaesthesia, and electrolyte imbalances (see also next section for the effect of hormonal disturbances on fluid therapy). A multimodal approach to postoperative analgesia is recommended, extended by loco-regional pain management in a paracostal approach.
Intra-or postoperative haemorrhage and thromboembolism are important complications directly related to adrenal tumour removal. Intravascular tumour extension may have a predisposing role in these complications. In our experience, wound infection and poor wound healing are rare complications.

**Hormonal Disturbances**

Prior to surgery, hormonal disturbances—specifically hypersecretions—should be controlled medically in an attempt to limit their detrimental consequences in the direct perioperative period. If this cannot be achieved, the detrimental clinical consequences of the hormonal hypersecretion should be assessed and treated accordingly in preparation for surgery.

Upon removal of hypersecretory tumour tissue at surgery, hormonal replacement therapy should be instituted to supplement the chronic suppression of hormone secretion in the contralateral adrenal gland. Bilateral adrenalectomy necessitates full glucocorticoid and mineralocorticoid replacement, independent from the type of tumour removed.

**Hypercortisolism**

An attempt to control hypercortisolism and thereby improve the condition prior to surgery is rarely undertaken, although several preoperative medical treatment options have been suggested in adrenal tumour hypercortisolism (e.g., mitotane, trilostane). The reduction in size seen in some adrenal tumours after medical treatment could also be an additional advantage in preparation of surgical removal of relatively large tumours.

The effects of long-term hypercortisolism can be detrimental to the clinical condition of the patient prior to surgery. Hypercortisolism can induce several accumulating negative effects on the patient’s respiration, severely hampering pulmonary gas exchange and heat exchange: decreased functional residual capacity, decreased lung and chest wall compliance and diminished vital capacity due to intra-abdominal and peri-thoracic fat deposition, muscle wasting/weakness, pulmonary mineralization, (micro)thromboembolism, and pneumonia. Gas exchange and heat tolerance can be further compromised by age-, breed-, and hypercortisolism-related factors such as upper airway collapse, (sub)clinical heart disease, and arterial hypertension.

Hyperglycaemia as a result of diabetes mellitus is common in hypercortisolism and often complicates perioperative stabilisation. Moderate to severe hyperglycaemia should be controlled prior to admittance for surgery. In the postoperative period, because of the expected insulin resistance and the risk of diabetic ketoacidosis, the author prefers the use in the immediate postoperative period of an insulin treatment protocol based on continuous rate infusion (CRI) with a neutral, regular insulin.

Although pulmonary thromboembolism is considered a common perioperative complication, it often remains a suspicion and rarely becomes a confirmed diagnosis. A sudden and unexplained increase in respiratory distress could indicate a thromboembolic event. While several diagnostic (imaging) modalities can be considered, treatment options in veterinary medicine remain limited.
Hypernatraemia may develop postoperatively because of excess free water loss via the urine. Drinking water should be offered as soon as possible in the recovery period. However, if the patient is reluctant to drink, intravenous fluid therapy, often with fluids containing free water, should be initiated immediately to control plasma sodium levels until the patient is able to maintain a normal fluid balance. In an attempt to control plasma sodium levels early on, free water administration is often initiated during anaesthesia by administering half-strength saline spiked with 4 mmol/l potassium chloride as maintenance fluid.

Replacement hormonal therapy for unilateral adrenalectomy has been described.\(^9\) In bilateral adrenalectomy, lifelong substitution with a glucocorticoid and mineralocorticoid is required following the treatment protocol for primary hypoadrenocorticism.\(^10\) Further adjustments should be made based on additional clinical assessment of the patient and electrolyte levels.

**Hyperaldosteronism**

Primary hyperaldosteronism leads to systemic arterial hypertension, hypokalaemia, and/or hypernatraemia. Most affected cats present with muscular weakness and/or signs of end-organ damage caused by chronic arterial hypertension (retinal damage, renal failure, cardiac disease with arrhythmias). As diagnosis is often delayed, cats are frequently presented in poor clinical condition, suffering from severe dehydration, anorexia, weight loss, hepatic lipidosis, and chronic anaemia.

Hypertension as a result of plasma and interstitial fluid expansion and vasoconstriction due to hyperaldosteronism may be controlled preoperatively with a mineralocorticoid receptor blocker such as spironolactone (initial dose is 2 mg/kg bodyweight orally q 12 h) in combination with antihypertensive medication like amlodipine (initial oral dose of 0.1 mg/kg body weight q 24 h). Treatment should be guided by arterial blood pressure measurements. If the patient is dehydrated and hypovolaemic on presentation, fluid balance should be restored prior to arterial blood pressure evaluation and antihypertensive treatment.

Pre- and perioperative hypokalaemia and concurrent hypomagnesaemia should be controlled by the combination of spironolactone and intravenous, or oral, potassium and magnesium supplementation. Especially preoperative hypokalaemia may be very persistent, because hyperaldosteronism and concomitant hypomagnesaemia result in ongoing renal losses. Furthermore, as an intracellular electrolyte, plasma potassium and magnesium levels may be a poor reflection of total body stores.

During the first few weeks after surgery, a generous dietary intake of sodium may be provided to avoid hyperkalaemia resulting from the chronic suppression of aldosterone secretion in the contralateral adrenal. Temporary administration of fludrocortisone could also be considered but is often not necessary.\(^11\)

Any other complications, such as cardiac arrhythmias and other electrolyte disturbances - such as in plasma phosphate and bicarbonate levels - are dealt with accordingly.

**Hypercatecholaminism**
The main and most important objective in the treatment of hypercatecholaminism ([nor]adrenaline and dopamine) is the control of the hypersympathetic drive leading to severe hypertensive episodes and tachyarrhythmias prior to and in the perioperative period.

Several drugs have been recommended for this purpose, including selective and non-selective alpha- and beta-adrenoceptor antagonists, calcium channel blockers, and drugs that either reduce catecholamine release ($\text{MgSO}_4$)\textsuperscript{12,13} or inhibit catecholamine synthesis (a-methylparatyrosine)\textsuperscript{14}. Experience in veterinary medicine with drugs that reduce plasma catecholamine levels is limited.

Perioperative stabilisation is, unfortunately, not easily achieved in some patients due to unpredictable and sudden increases in the secretion of catecholamines (mainly adrenaline). The cause of these fluctuations may be unknown or triggered by anaesthesia, contrast media, and tumour manipulation. As the effectiveness of blocking agents, especially of alpha-receptors, is limited in these situations, inhibition of catecholamine release in the pre- and perioperative period seems therefore warranted. The attempt to control sympathetic drive may also lead to severe hypotension, hypovolaemia, and hypoglycaemia perioperatively.

Most veterinary protocols are based on controlling hyperadrenalism preoperatively with the use of phenoxybenzamine, a nonselective, noncompetitive alpha-adrenoreceptor antagonist (starting dose 0.25 mg/kg per os q 12 h for 1 to 2 weeks).\textsuperscript{15} Its dosage should be adjusted until signs of hypotension and/or adverse drug reactions are experienced, or if a maximum dose of 2.5 mg/kg q 12 h is attained. Intraoperatively (and postoperatively when unresectable metastases are present at surgery), a short-acting alpha-blocker, phentolamine, can be used IV (initial or incremental doses of 0.1 mg/kg to effect followed by 1–2 $\mu$g/kg/min).

Following effective alpha-blockade, severe episodes of (negative feedback escape) tachycardia may be controlled with a beta-blocker such as propranolol or atenolol prior to surgery, and by esmolol in the immediate perioperative period. Alternatively, specific alpha\textsubscript{1}-blockade (doxazosin and prazosin) may be instituted,\textsuperscript{14} reducing beta-blocker requirements perioperatively.

Severe hypertension may also be managed with the use of calcium channel blockers or possibly MgSO\textsubscript{4}, which, besides limiting catecholamine release, acts as a calcium antagonist in these instances.

Severe and acute fluctuations in blood pressure and heart rate, cardiac arrhythmias, and haemorrhage can occur during surgery and in the immediate postoperative period. Telemetric electrocardiogram and continuous invasive arterial blood pressure measurement are mandatory. Chronic catecholamine-induced vasoconstriction may lead to severe plasma volume reduction. In combination with sudden loss in sympathetic drive, the prolonged effects of antihypertensive drugs (especially phenoxybenzamine) can cause severe postoperative hypotension. Postoperative volume expansion with judicious but aggressive fluid therapy is often necessary to stabilise blood pressure. Increased preoperative sodium intake has been suggested in human medicine to anticipate postoperative hypotension.

**Hypersecretion of Sex Hormones**
In contrast to ferrets, hypersecretion of sex hormones leading to a clinical syndrome is considered rare in dogs and cats. Surgical intervention does not necessitate prior or postoperative control of sex hormone imbalances.

**CONFLICT OF INTEREST STATEMENT**

No COI were declared.

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