Long-term management of the diabetic dog

Linda M. Fleeman BVSc, MACVSc
Jacquie S. Rand BVSc, DVSc, DipACVIM
University of Queensland, Australia

KEY POINTS

- Insulin is the mainstay of therapy for diabetic dogs.
- The majority of diabetic dogs require twice-daily administration of insulin to control their signs.
- Insulin and dietary recommendations need to be tailored for each diabetic dog.
- A consistent insulin-dosing and feeding routine is optimal, although not critical. For practical reasons, a certain amount of compromise may be necessary, and is often not associated with significant clinical consequences.
- The diet fed should primarily be palatable and nutritionally balanced.
- Results of recent studies indicate that improved glycaemic control may be achieved in the majority of diabetic dogs if their diet contains increased insoluble fibre.
- Decreased dietary fat content is recommended if there is concurrent disease of the exocrine pancreas.
- Blindness due to cataract formation occurs in the majority of diabetic dogs.

Introduction

Diabetes mellitus is a common endocrine disease of middle-aged and older dogs characterised by an absolute or relative deficiency of insulin (1). Insulin administration is the mainstay of therapy in all affected dogs, with long-term treatment involving injections given once or twice each day by the owner. The cause of diabetes in dogs has been poorly characterised and is undoubtedly multifactorial. Genetic predisposition exists (1) and immune-mediated destruction of pancreatic beta-cells has been shown to occur in affected dogs (2–5).

Clinical presentation

Dogs with uncomplicated diabetes mellitus classically present with polyuria, polydipsia, weight loss, an increased appetite, and lethargy. Most affected dogs are over seven years of age and females are at greater risk than males (6, 7). The onset of these classic clinical signs is typically chronic, ranging from weeks to months (6), and may initially be unnoticed or considered insignificant by the dog's owner. If ketosis and metabolic acidosis develop, more serious systemic signs, such as vomiting and anorexia, are seen and prompt owners to seek veterinary care more rapidly. Approximately 40% of

Linda Fleeman
BVSc, MACVSc

Dr. Fleeman graduated with honours from the University of Queensland in 1984. She worked in first opinion small animal practice for eight years and subsequently in referral practice for five years. She completed a three year medicine internship at Murdoch University and a Clinical Residency at the University of Melbourne. Currently she is completing a PhD research project investigating canine diabetes mellitus at the University of Queensland, working with Dr Rand.

Jacquie Rand
BVSc, DVSc, DipACVIM

Dr. Rand graduated with honours from the University of Melbourne in 1975. She worked in private practice for eight years before completing a residency and doctorate at the University of Guelph in Canada. After a three-year position as a Clinical Registrar at the University of Zurich in Switzerland she returned to Australia in 1990. Currently she is an Associate Professor in companion animal sciences at the University of Queensland. Her primary area of research is in canine and feline diabetes and obesity.

Table 1

Commonly available insulin preparations and their effects following subcutaneous injection in dogs.

Type of insulin	Source	Onset of effect	Time of maximal effect	Duration of effect
Regular* and semilente	Recombinant human Bovine	10–30 min	1–5 h	4–10 h
Isophane* (NPH)	Recombinant human	0.5–3 h	2–10 h	4–24 h
Lente**	Purified porcine Recombinant human Bovine	< 1 h 2–10 h (1)	4–8 h (10) 6–24 h (1)	14–24 h (56)
Protamine zinc insulin (PZI)	90% bovine, 10% porcine 100% bovine	1–4 h 8–20 h (10)	4–14 h (1)	6–28 h (10)
Ultralente	Recombinant human	1–8 h	4–16 h	8–28 h

**Premixed combinations of human NPH and regular insulin are available: 20% Regular/80% NPH; 30% Regular/70% NPH; 50% Regular/50% NPH.*
***Lente insulin contains 30% semilente and 70% ultralente insulin.*
(Modified from reference 1)

diabetic dogs were found to have already developed ketosis by the time they were first presented to a university teaching hospital (6). This progression to a more complicated diabetic patient often coincides with the development of concurrent disease such as pancreatitis or bacterial infection of the skin, mucosal surfaces, or urinary tract.

Cataract formation is the most common and one of the most important long-term complications associated with diabetes in the dog (1). It is an irreversible process once it begins, and can progress quite rapidly. One survey found that approximately 30% of diabetic dogs already had reduced vision at presentation, and about half of the remaining dogs became blind within two years (8). A larger study concluded that cataracts will develop within five to six months of diagnosis in the majority of diabetic dogs, and that within 16 months approximately 80% will have significant cataract formation (9).

Insulin deficiency results in altered carbohydrate, fat, and protein metabolism. Abnormal carbohydrate metabolism manifests as hyperglycaemia and glycosuria and is responsible for the polyuria, polydipsia, and cataract formation seen in diabetic dogs. The hyperlipidaemia, ketone production, and hepatic changes seen in these dogs primarily result from altered fat metabolism. Decreased tissue utilisation of glucose, amino acids, and fatty acids is the cause of the lethargy, weight loss, reduced stimulation of the satiety centre, poor coat, and reduced immunity that is characteristic of untreated diabetic dogs.

Figure 1 *Diabetic cataracts:* **(a)** *Photograph of a diabetic dog shortly after diagnosis of diabetes mellitus.* **(b)** *The same dog three months later and after successful stabilisation on insulin therapy. Diabetic cataracts had developed rapidly and the dog's owners had reported sudden loss of vision.* **(c)** *The same dog following phacoemulsification surgery to remove the cataract from the right eye.*

Therapy

Aims of therapy

The three primary aims of long-term therapy for diabetic dogs are:

- Resolution of all clinical signs
- Avoidance of insulin-induced hypoglycaemia
- Resumption of usual lifestyle and exercise level

Lethargy tends to resolve rapidly and dogs become more active and responsive soon after initiation of insulin therapy. Weight loss is usually arrested before optimal glycaemic control is achieved, but complete resolution of the polyuria and polydipsia will not occur until the blood glucose can be kept below the renal threshold. In the majority of diabetic dogs the process of cataract formation has unfortunately already been initiated before adequate control of hyperglycaemia can be achieved (**Figure 1**).

Insulin

A variety of insulin preparations with both prompt and prolonged actions are commonly available (**Table 1**). Regular and semilente insulins are characterised by rapid action and short duration of effect and are generally not useful for the long-term management of diabetic dogs. Longer-acting preparations such as ultralente, protamine zinc insulin (PZI), and isophane (NPH) are more suited as they provide continued insulin supplementation for many hours after a single injection. Premixed combinations of short- and longer-acting insulins are valuable for the

treatment of diabetic dogs. One common example is lente insulin, which contains a mixture of semilente and ultralente, and results in a relatively predictable and rapidly obtained peak effect (10). A number of combinations of regular and NPH insulin are also widely available.

When choosing the type of insulin for long-term use in a diabetic dog, another consideration is the species of the exogenous insulin. Porcine insulin has exactly the same amino acid sequence as canine insulin and induces no anti-insulin antibodies with prolonged use in dogs (11–14). Human insulin differs by one amino acid from canine insulin and anti-insulin antibodies have been detected in only one dog treated with recombinant human insulin (15). Bovine insulin differs by two amino acids from canine insulin. Anti-insulin antibodies have been detected in dogs treated with both purified bovine (11) and mixed bovine/porcine insulin (13, 15). These anti-insulin antibodies may affect glycaemic control in some diabetic dogs treated with bovine/porcine insulin (15) and so it may be advisable to avoid preparations that contain bovine insulin.

Human recombinant insulins are usually sold at a concentration of 100 IU/ml. In some countries, porcine lente insulin or bovine/porcine PZI insulin are available at a concentration of 40 IU/ml. These more dilute preparations are useful for smaller dogs, which may require a total insulin dose of only one or two international units. Syringes that measure international unit increments are available for both insulin concentrations. Insulin-dosing pens are obtainable for NPH insulin and the premixed combinations of regular and NPH insulin. Most of these dosing pens allow injection of a minimum dose of 2 IU and increase in 1 IU increments, making them a practical tool for smaller patients.

In a small proportion of diabetic dogs, good glycaemic control can be attained with once-daily administration of one of the longer-acting insulins. The majority of diabetic dogs, however, require twice-daily administration of insulin to control their clinical signs adequately (1, 12, 16). Although treatment regimens comprising once-daily insulin injections are considered by many to be simpler and more convenient, most of these regimens involve feeding meals twice daily. Owners of diabetic dogs often find that having to be at home with their dog at set times twice each day is the main intrusion into their daily routine. Experienced owners rarely report any difficulty with the administration of insulin injections and therefore if they are required to be at home to feed the dog it is little more effort to give the dog an insulin injection at the same time. As a result, many clinicians favour treatment regimens that involve administration of the same dose of insulin along with feeding of the same-sized meal every 12 hours. If lente insulin (12) or a premixed combination of regular and NPH insulin is chosen, the onset of effect and the period of maximal insulin activity will then roughly match the expected postprandial absorption of nutrients.

Diet

The food fed to diabetic dogs should provide adequate calories to achieve and maintain optimal body condition. Dogs with poorly controlled diabetes have a decreased ability to metabolise the nutrients absorbed from their gastrointestinal tract and lose glucose in their urine, so require more calories for maintenance than healthy dogs. The diet fed should be nutritionally balanced and needs to be palatable so that food intake is predictable. Meals should ideally be timed so that maximal exogenous insulin activity occurs during the postprandial period (12). Because the daily insulin-dosing regimen tends to be fixed for diabetic dogs, it is also important that a predictable glycaemic response is achieved following each meal. Consequently, every meal should contain roughly the same ingredients and calorie content, and should be fed at the same times each day. The owners of diabetic dogs should be aware that a consistent insulin-dosing and feeding routine is optimal although, for practical reasons, a certain amount of compromise may be necessary in individual cases.

For several decades, there has been a great deal of interest in research into the composition of an optimal diet for people diagnosed with the various forms of diabetes mellitus. As a result, it is now recognised that dietary management plays a central role in the treatment of diabetic people. More recently, veterinary researchers have started to follow this trend and comparison can now be made between the dietary recommendations for diabetic people and those for dogs (**Table 2**).

Table 2

Current nutritional recommendations for human diabetics (17) and canine diabetics (1) compared with the nutritional requirements of non-diabetic populations

Dietary factor	Human diabetics	Canine diabetics
Carbohydrate content	Increased	Increased
	High proportion of *soluble* fibre and complex carbohydrates	High proportion of *insoluble* fibre and complex carbohydrates (18, 19)
Fat content	Decreased	Decreased
Protein content	Same	Same

Dietary fibre and complex carbohydrates – current recommendations for diabetic people

Before the advent of insulin therapy, fat and protein were the main sources of energy in the diets prescribed for people with diabetes. Dietary carbohydrate was avoided in an effort to reduce hyperglycaemia. Diets currently recommended for diabetics are the result of substitution of the saturated fat content with complex carbohydrates. The primary reason for this change was the realisation that the risk of death due to cardiovascular disease could be greatly reduced by lowering plasma cholesterol. Many protein sources contain significant amounts of fat and so are not practical replacements for dietary fat. Consequently, the only option that remained was to increase the carbohydrate component. It has been consistently shown that the cholesterol content of low-density lipoproteins is significantly reduced in diabetic people when complex carbohydrates are substituted for the saturated fat content of their diet (20). It is now highly recommended that 55 to 60% of a diabetic person's total energy should be provided from carbohydrate and the majority of the carbohydrates should be complex, containing high amounts of resistant starch and fibre (21). Classification of foods according to their acute glycaemic effects has been suggested as a means of identifying which carbohydrate-containing foods are optimal for people with diabetes (17). Foods such as pulses, oats, and barley, which have been found to have a low glycaemic index, may be the most beneficial.

In human diabetics, high-carbohydrate intake can be associated with increased blood glucose fluctuations and hypertriglyceridaemia. However, when the effects of high carbohydrate diets containing soluble fibre are compared with those of high-carbohydrate/low-fibre diets, patients consuming soluble fibre tend to have lower glycosylated haemoglobin levels (22), lower postprandial blood glucose values, and the hypertriglyceridaemic effect is attenuated or abolished (23). Digestible carbohydrate needs to comprise more than 40% of caloric intake to ensure maximal beneficial effects of the fibre. Only soluble fibre has a hypoglycaemic and hypolipidaemic effect, whereas insoluble fibre appears to have no effect at all (24). The primary mechanism appears to be the ability of certain soluble fibres, such as guar gum, to form a viscous gel and thus impair transfer of nutrients to the absorptive surface of the intestine (25).

It should be remembered that exogenous insulin has an overwhelming effect on carbohydrate metabolism. In diabetic people with absolute insulin deficiency, dietary manipulations are still an adjunct to insulin therapy. The results of a recent study help to put the role of diet into perspective (26).

The effects of foods with different glycaemic indexes and fibre content were examined in a small number of well-controlled diabetic patients treated with intensive insulin therapy. It was found that, although diets with a low glycaemic index resulted in lower fasting plasma glucose, and diets with increased soluble fibre reduced the postprandial rise in plasma glucose, the difference was not sufficient to require adjustment of the patients' insulin doses.

What is dietary fibre?

Fibre is a term used to describe the most complex and least definable component of foods of plant origin, encompassing a diverse group of plant polysaccharides, mucilages, and phenolic compounds (27). Dietary fibre is in fact a shorthand expression that covers a wide variety of entities and should be considered a concept, rather than a definable substance. Diverse methods of fibre analysis exist, all measuring something different. The same analysis performed by different laboratories can produce dissimilar results. Crude fibre is the figure most widely quoted on pet food labels and is the residue remaining after extraction of a food material with dilute acid or alkali. It substantially underestimates the total dietary fibre of common ingredients used in commercial pet food and dietary fibre supplements and is largely obsolete in the field of human nutrition (27).

Analysis techniques that quantify the individual sugars comprising the polysaccharides also partition the dietary fibre into soluble and insoluble fractions, a reflection of their properties in an aqueous media. Soluble fibre has great water-holding capacity, forms a viscous solution in water, and is readily degraded by colonic microflora in dogs to produce short-chain fatty acids that are absorbed across the intestinal mucosa. It has been proposed that these fatty acids stimulate secretion of intestinal hormones that modulate the nutrient transport capacity of the gut and promote insulin secretion, which together facilitate removal of glucose from the circulation (28). A recent study indicated that dogs fed diets with increased viscosity may actually have more rapid postprandial glucose absorption, resulting in higher total postprandial glucose absorption, and are more likely to develop secretory diarrhoea than dogs fed diets with lower viscosity (29). This suggests that only diets with an intermediate viscosity level may be associated with a delay in gastrointestinal transit time and optimal glucose homeostasis in dogs. Dogs cannot digest the insoluble fibre component of their diet and it is excreted in the faeces. In contrast to soluble fibre, insoluble fibre seems to exert relatively little physiological effect in the canine gut and can be tolerated in fairly high dietary levels (27). Most foods contain more insoluble than soluble fibre, even those that are commonly quoted as sources of soluble fibre, such as guar gum.

Perhaps the most useful method of defining dietary fibre is to consider the source of the fibre. Fruits, legumes, oats, barley, and psyllium husks tend to contain more soluble fibre than cereals and vegetables, although there are exceptions. Pea fibre (purified pea hulls), arbocell (purified cellulose), oat bran, wheat bran, and guar gum are all sources of fibre that are used as ingredients in commercial pet food or as dietary fibre supplements (**Figure 2**). One of the main advantages of high-fibre diets is that intestinal glucose absorption is slowed, so the fibre should always be incorporated in the food rather than given separately as a supplement.

Dietary fibre and complex carbohydrates – current recommendations for diabetic dogs

Studies in diabetic dogs indicate that high-fibre diets may also be associated with improved glycaemic control in this species (18, 19, 30–32). When dogs were fed a single meal containing either increased soluble fibre or increased insoluble fibre, a greater reduction of postprandial hyperglycaemia was seen with the meal containing soluble fibre (30). However, when comparison was made following long-term feeding of high-soluble-fibre diets and high-insoluble-fibre diets for one or two months

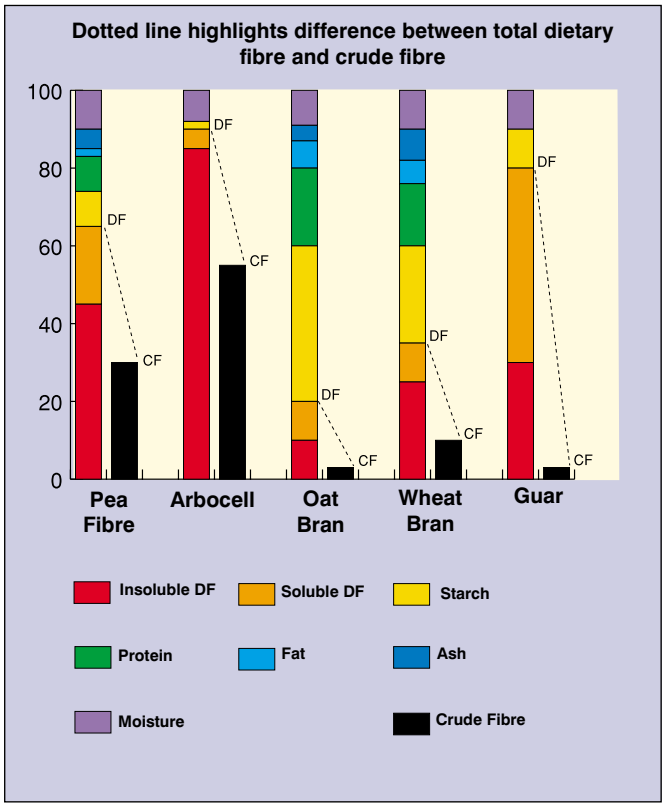


Figure 2 *Analysis of five fibre supplements used in commercial dog food.*
NB. This illustration first appeared in Bauer, J.E., Maskell, I.E. Dietary fibre: Perspectives in clinical management. In: Wills, J. M., Simpson, K. W. (eds.) The WALTHAM Book of Clinical Nutrition of the Dog and Cat. *Oxford: Pergamon, 1995: 87–104. Analysis of five fibre supplements, demonstrating the poor correlation between total dietary fibre and crude fibre. Data are from the analytical laboratory at Pedigree Petfoods, Melton Mowbray.*

(18, 19), a tendency for improved glycaemic control and fewer side effects was seen with the diets containing increased insoluble fibre. In particular, significantly lower glycosylated haemoglobin (18) or fructosamine (19) levels were recorded. Regardless of the composition of the high-fibre diet, or the length of time over which the dogs are monitored, no significant difference in daily insulin requirement (18, 19, 30–32) or fasting triglyceride (18, 32) between groups of diabetic dogs fed low-fibre and high-fibre diets has been found.

Importantly, there seems to be marked variation between the responses of individual diabetic dogs to dietary fibre. In one study (32), significant improvement of all indices of glycaemic control, including lowered daily insulin requirement, was seen in nine of 11 dogs when they were fed a high-fibre diet. The remaining two dogs were found to have improved glycaemic control on the low-fibre diet. A similar situation exists for people because high-carbohydrate high-fibre diets are not uniformly effective in all diabetic subjects (21). This may be partly due to the side effects that are sometimes associated with high-fibre diets, which include poor palatability, poor weight gain, poor hair coat, voluminous faeces, flatulence, diarrhoea, and constipation.

In comparison with the bulk of literature addressing the influence of dietary fibre on human diabetes, the number of studies that have investigated this aspect of canine diabetes is very small. Although there is no doubt that a considerable amount of the information that is now known about dietary recommendations for human patients is also relevant to dogs, it is clear that the specific requirements of diabetic dogs need further clarification. The influence of high-fibre and low-fibre diets has been studied in diabetic dogs; however, little comparison has been made with

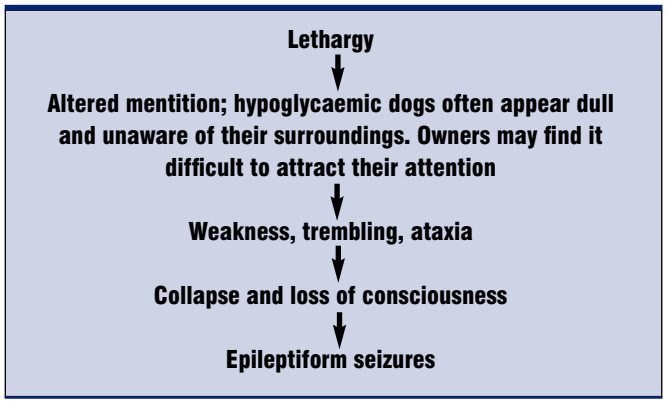


Figure 3 *Progression of clinical signs as hypoglycaemia becomes more severe in dogs.*

typical maintenance diets to see if increased fibre results in measurable benefits compared with a conventional diet. Future studies will help to determine more accurately the optimal quantity, type, and source of dietary fibre used. The influence of the manner of processing the dietary fibre and the effect of the composition of the digestible carbohydrate component of the diet also require elucidation. Ultimately, clinicians will want to know how commercially available high-fibre diets, compared with the typical maintenance moderate-fibre diets, will influence the clinical management of their patients. The owners of diabetic dogs, on the other hand, are likely to be more interested in the palatability and side effects of any high-fibre diets that are recommended for their pets.

Dietary fat

Altered lipid metabolism occurs in both people and dogs with insulin deficiency. In humans, the lipid disorders that occur in association with diabetes are arthrogenic and predispose to coronary artery disease, cerebrovascular disease, and peripheral arterial disease (33). Low-fat diets have been shown to reduce cardiovascular morbidity and mortality in diabetic people. Fortunately, atherosclerosis and arterial disease are not clinical concerns in diabetic dogs. However, it has been known for some time that a large proportion of diabetic dogs have exocrine pancreatic disease (6, 34–40). High-fat diets and hypertriglyceridaemia have been proposed as possible inciting causes of canine pancreatitis (41) and low-fat diets are recommended for dogs with chronic pancreatitis and exocrine pancreatic insufficiency. As it can be difficult to identify those diabetic dogs with subclinical exocrine pancreatic disease (42), it may be prudent to consider feeding a reduced fat diet to all diabetic dogs.

Table 3

Summary of current dietary recommendations for diabetic dogs

Calorie intake	Achieve and maintain optimal body condition
Primary nutritional requirements	Palatable Nutritionally balanced Consistency is important The same food containing a standard number of calories should be fed following each insulin injection
Other nutritional recommendations	Increased complex carbohydrate content with a high proportion of insoluble fibre incorporated into the food Decreased fat content, particularly if there is concurrent disease of the exocrine pancreas
Timing of meals	Postprandial period should ideally coincide with the period of maximal exogenous insulin activity Feed multiple small meals or two equal-sized meals per day
Diabetic dogs with concurrent disease	The nutritional requirements of any concurrent disease should take precedence over the dietary therapy for diabetes Regardless of the diet fed, glycaemic control can still be maintained with exogenous insulin therapy

Dietary protein

The protein composition of the recommended diet for people with diabetes is the same as that recommended for the non-diabetic population. However, if microalbuminuria or persistent proteinuria develop, then protein restriction may help slow the progression of diabetic nephropathy in these people (24). The optimal dietary protein for diabetic dogs has not been determined. It is currently recommended that dietary protein should meet daily requirements, but not be excessive (1). Microalbuminuria and proteinuria do occur in diabetic dogs (43) and lower dietary protein intake may be indicated in these animals.

The dietary recommendations for diabetic dogs are summarised in **Table 3**.

Information from research using healthy dogs that may prove relevant for diabetic dogs

Little is known about the glycaemic responses of dogs to various carbohydrate-containing foods. It has been found that a semimoist food containing corn syrup, compared with a canned and a dry food that did not contain corn syrup, resulted in a significantly greater postprandial glycaemic response when fed to healthy dogs (44). A more recent study examining the postprandial effects of five diets with equivalent starch content from different cereal sources found marked differences in the glucose and insulin responses of healthy dogs (45). The rice-based diet resulted in significantly higher postprandial glucose and insulin responses. Sorghum generally caused the lowest postprandial glucose response while barley produced the lowest insulin response. These findings form an interesting basis for future study on the effects of diets containing barley and sorghum in diabetic dogs, but more work is required before specific recommendations can be made. It is worth noting that studies in human beings have found a marked variability in the glycaemic response to different types of barley (46) and rice (47).

Chromium tripicolinate is a dietary mineral supplement that has been shown to increase the clearance rate of glucose from the blood by approximately 10% in healthy dogs (48). Chromium is an essential nutrient, not a drug, and therefore supplementation may result in benefits only if the individual is deficient or marginally deficient in chromium. It is now clear that dietary chromium levels of most people in industrialised countries are suboptimal (49). Similar information is not available for dogs and further studies are warranted to try and establish the minimum recommended dietary chromium intake for healthy dogs. Chromium is thought to potentiate insulin's ability to store glucose and would theoretically be a useful adjunct to exogenous insulin therapy. It is also possible that inadequate dietary intake of chromium by dogs may increase their risk of developing diabetes. It has been postulated that some insulin-dependent diabetics may lose their ability to convert inorganic chromium to the biologically active form and may actually need to consume foods that contain active forms of chromium (50). At this stage, there is little information available on the effects of chromium supplementation in human patients requiring insulin therapy (51, 52). Feeding trials using diabetic dogs are indicated to determine the effects of dietary chromium supplementation in these animals.

Establishing a practical routine for the owner

The first aim of long-term therapy of diabetic dogs is resolution of the

clinical signs. In other words, well-controlled diabetic dogs are not lethargic, maintain optimal body condition, drink less than 60 ml of water per kg body weight during a 24-hour period, and have no ketonuria.

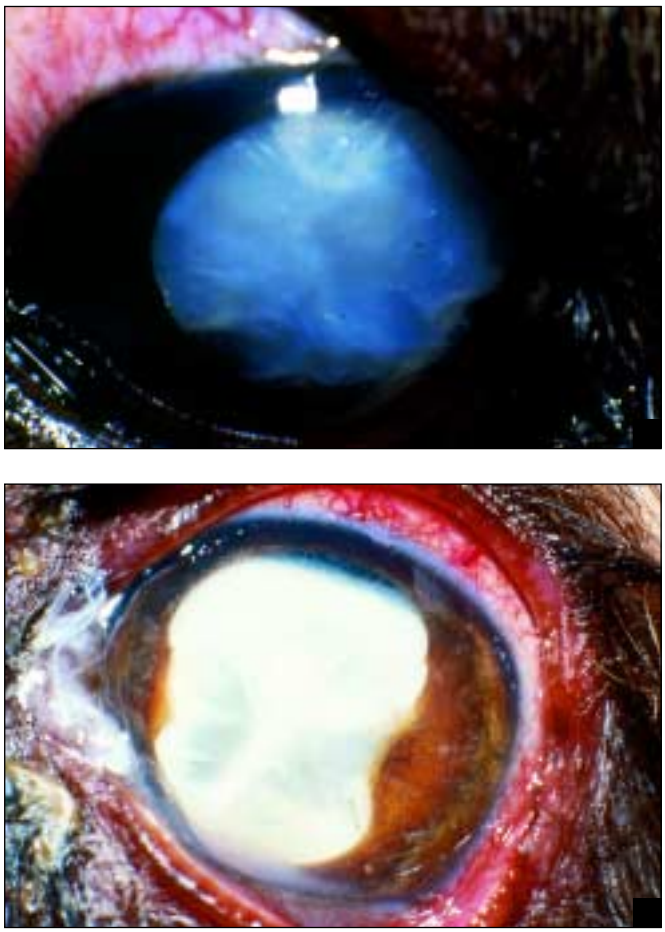
Many different regimens have been used to achieve this successfully and it is usually possible to introduce a number of modifications to the treatment strategy of individual dogs without compromising their clinical response. Ideally, exogenous insulin should remain effective throughout every 24-hour period and meal feeding should be timed so that the postprandial periods coincide with maximal insulin activity. Typically, this entails feeding the dog some time after each insulin injection. However, it is often more convenient for owners to feed their dog at the time of injection and many prefer this as they feel their pet is rewarded for submitting to the injection. It is the authors' experience that good control of clinical signs can readily be achieved in diabetic dogs that are fed meals at the time of insulin injections. Care should be taken to consider each case individually. It is usually possible to make practical modifications to any treatment regimen in order to reduce the disruption to the owner's lifestyle.

The second goal of therapy is avoidance of insulin-induced hypoglycaemia. Every person in the diabetic dog's household needs to be aware of this life-threatening complication, which can rapidly develop into a frightening emergency. The importance of avoiding an insulin overdose cannot be overemphasised. If some insulin is spilt during injection it should never be 'topped up', even if it appears that the dog has received no insulin. If the owner is ever uncertain, the safest option is to withhold the injection as the consequences of missing a single insulin dose are negligible. The clinical signs seen in dogs with hypoglycaemia are listed in **Figure 3**. If mild signs of hypoglycaemia develop, the owner should feed a meal of the dog's usual food. If the dog is unwilling or unable to eat, syrup containing a high glucose concentration can be administered orally. Suitable syrups are marketed for use by human diabetics. When the dog recovers, food should be fed as soon as possible. No more insulin should be given to the dog until the case is discussed with a veterinarian, at which point a 50% reduction in insulin dose is usually recommended. Care must be taken when dispensing insulin syringes to owners to ensure that there is no confusion regarding dosing. For example, the gradations on many 1 ml insulin syringes are equal to 2 IU, while gradations of 1 IU are present on most 0.5 ml insulin syringes. Gradations on syringes designed for use with 100 IU/ml insulin represent a different volume from gradations on syringes designed for use with 40 IU/ml insulin, and this may lead to dosing errors.

The final goal of long-term therapy of diabetic dogs is resumption of the pet's usual lifestyle and exercise level. Most owners of diabetic dogs will take one to two weeks to establish a daily treatment routine and to become accustomed to administration of subcutaneous injections. A period of adjustment and stabilisation of therapy follows. Good glycaemic control is usually attained after at least two months of reappraisal and insulin dosage adjustment. Once this stage is reached, further clinical improvement may still be seen for several weeks before the dog achieves an optimal health and fitness level. Many diabetic dogs are elderly and are accustomed to moderate daily exercise. Younger dogs may resume a very high activity level and require further adjustment to their daily calorie intake and insulin dose as a result.

Concurrent disease

Most diabetic dogs are middle aged and older and so are prone to diseases that commonly affect this age group. Consequently, many suffer concurrent problems that cause insulin resistance and need to be managed in combination with the diabetes. Treated diabetic dogs have a similar chance of survival to that of non-diabetic dogs of the same age and gender, although the hazard of death occurring is greatest during the first six



Illustrations courtesy Dr Richard I E Smith of Animal Eye Services at the University of Queensland.

Figure 4 (a) *A hypermature cataract in a diabetic dog. Some scleral hyperaemia is present, indicating that there is also mild, lens-induced uveitis.* **(b)** *Severe, lens-induced uveitis in a diabetic dog. The eye is red and painful. There is significant ocular discharge and posterior synechiae are present.*

months of therapy (53). Insulin resistance associated with hyperadrenocorticism is a relatively common problem in diabetic dogs (40) and can present a diagnostic and therapeutic challenge. Chronic pancreatitis also complicates the management of some dogs with diabetes. Reduced immunity often remains a feature of treated diabetic dogs and many are at increased risk for developing bacterial infections, particularly of the skin and the urinary tract. Regular urine culture may be advisable, even if urinary tract signs are not present (54). Ovariohysterectomy is recommended for entire bitches, as insulin resistance occurs during the long progesterone phase of their cycle (1).

Blindness and lens-induced uveitis develop sooner or later in the majority of diabetic dogs and are the single most important sequelae for this condition (1). Mild or subclinical uveitis is present in most dogs with diabetic cataracts and can often be satisfactorily managed with oral non-steroidal anti-inflammatory drugs such as aspirin (55). Permanent ocular damage can result if lens-induced uveitis is not treated (**Figure 4**). Surgical removal of diabetic cataracts usually results in restoration of good vision and marked improvement of the dog's quality of life.

Conclusion

Successful long-term management of a diabetic dog sometimes requires permanent changes to the lifestyles of both owner and dog and so

individualisation of the advice given is imperative. A relationship based on trust and co-operation between veterinarian and client invariably leads to the most satisfactory outcome. The ongoing treatment of a diabetic dog can be one of the more rewarding experiences of small animal practice and many diabetic dogs and their owners come to occupy a special place within the clinic environment.

● REFERENCES ●

1. Feldman, E. C., Nelson, R. W. Diabetes mellitus. In: Feldman, E. C., Nelson, R. W. (eds.) *Canine and Feline Endocrinology and Reproduction*, 2nd edn. Philadelphia: W. B Saunders, 1996: 339–391.

2. Sai, P., Debray-Sachs, M., Jondet, A., Gepts, W., Assan, R. Anti-beta-cell immunity in insulinopenic diabetic dogs. *Diabetes* 1984; **33**: 135–140.

3. Alejandro, R., Feldman, E., Shienvold, F. L., Mintz, D. H. Advances in canine diabetes mellitus research: Etiopathology and results of islet transplantation. *Journal of the American Veterinary Medical Association* 1988; **193**: 1050–1055.

4. Hoenig, M., Dawe, D. L. A qualitative assay for beta cell antibodies. Preliminary results in dogs with diabetes mellitus. *Veterinary Immunology and Immunopathology* 1992, **32**: 195–203.

5. Elie, M., Hoenig, M. Canine immune mediated diabetes mellitus: a case report. *Journal of the American Animal Hospital Association* 1995; **31**: 295–299.

6. Ling, G. V., Lowenstine, L. J., Pulley, T., Kaneko, J. J. Diabetes mellitus in dogs: A review of initial evaluation, immediate and long-term management, and outcome. *Journal of the American Veterinary Medical Association* 1977; **170**: 521–530.

7. Marmor, M., Willeberg, P., Glickman, L. T., Priester, W. A., Cypress, R. H., Hurvitz, A. I. Epizootiologic patterns of diabetes mellitus in dogs. *American Journal of Veterinary Research* 1982; **43**: 465–470.

8. Graham, P. A., Nash, A. S. Rates of blindness and other complications in diabetic dogs (abstract). In: *15th Annual Forum of the American College of Veterinary Internal Medicine*. Lake Buena Vista, USA, 1997: 671.

9. Beam, S., Correa, M. T., Davidson, M. G. A retrospective-cohort study on the development of cataracts in dogs with diabetes mellitus: 200 cases. *Veterinary and Comparative Ophthalmology* 1999; **2**: 169–172.

10. Church, D. B. The blood glucose response to three prolonged duration insulins in canine diabetes mellitus. *Journal of Small Animal Practice* 1981; **22**: 301–310.

11. Neubauer, H. P., Schone, H. H. The immunogenicity of different insulins in several animal species. *Diabetes* 1978; **27**: 8–15.

12. Church, D. B. Canine diabetes mellitus: some therapeutic considerations. In: Grunsell, G. S. G., Hill, F. W. (eds.) *Veterinary Annual*. Bristol: Scientechnica, 1982: 235–240.

13. Feldman, E. C., Nelson, R. W., Karam, J. H. Reduced immunogenicity of pork insulin in dogs with spontaneous insulin-dependent diabetes mellitus (IDDM) (abstract). *Diabetes* 1983; **32**(suppl 1): 153A.

14. Freiherr von Bolcshazy, G. Examination of immune reaction due to use of swine insulin in diabetic dogs (abstract). In: *Proceedings of the World Small Animal Veterinary Association conference*. Lyon, France, 1999.

15. Harb-Hauser, M., Nelson, R., Gershwin, L., Neal, L. Prevalence of insulin antibodies in diabetic dogs (abstract). In: *16th Annual Forum of the American College of Veterinary Internal Medicine*. San Diego, USA, 1998: 703.

16. Hess, R. S., Ward, C.R. Effect of insulin treatment on glycemic response in dogs with diabetes mellitus: 221 cases (1993–1998). *Journal of the American Veterinary Medical Association* 2000; **216**: 217–221.

17. Diabetes and Nutrition Study Group of the EASD. Nutritional recommendations for individuals with diabetes mellitus. *Diabetes Nutrition and Metabolism* 1988; **1**: 145–149.

18. Nelson, R. W., Ihle, S. L., Lewis, L. D. et al. Effects of dietary fiber supplementation on glycemic control in dogs with alloxan-induced diabetes mellitus. *American Journal of Veterinary Research* 1991; **52**: 2060–2066.

19. Kimmel, S., Michel, K., Hess, R., Ward, C. Effect of dietary fiber on glycemic control in diabetic dogs (abstract). In: *Proceedings of the 17th Forum of the American College of Veterinary Internal Medicine*. Chicago, USA, 1999: 708.

20. Howard, B. V., Abbott, W. G., Swinburn, B. A. Evaluation of metabolic effects of substitution of complex carbohydrates for saturated fat in individuals with obesity and NIDDM. *Diabetes Care* 1991; **14**: 786–795.

21. Anderson, J. W., Akanji, A. O. Dietary fiber – an overview. *Diabetes Care* 1991; **14**: 1126–1131.

22. Buyken, A. E., Toeller, M., Heitkamp, G. et al. Relation of fibre intake to HbA1c and the prevalence of severe ketoacidosis and severe hypoglycaemia. EURODIAB IDDM Complications Study Group. *Diabetologia* 1998; **41**: 882–890.

23. Riccardi, G., Rivellese, A., Pacioni, D., Genovese, S., Mastranzo, P., Mancini, M. Separate influence of dietary carbohydrate and fibre on the metabolic control in diabetes. *Diabetologia* 1984; **26**: 116–121.

24. Karamanos, B. The dietary management of diabetes. *Dialogue Diabetes Literature Review Service* 1998; **3**: 11–15.

25. Nuttall, F. Q. Dietary fiber in the management of diabetes. *Diabetes* 1993; **42**: 503–508.

26. Lafrance, L., Rabases-Lhoret, R., Poisson, D., Ducros, F., Chaisson, J.-L. Effects of different glycaemic index foods and dietary fibre intake on glycaemic control in type 1 diabetic patients on intensive insulin therapy. *Diabetic Medicine* 1998; **15**: 972–978.

27. Bauer, J. E., Maskell, I. E. Dietary fibre: Perspectives in clinical management. In: Wills, JM, Simpson, K. W. (eds.) *The Waltham Book of Clinical Nutrition of the Dog and Cat*. Oxford, Pergamon, 1995: 87–104.

28. McBurney, M. I., Massimino, S. P., Field, C. J., Sunvold, G. D., Hayek, M. G. Modulation of intestinal function and glucose homeostasis in dogs by the ingestion of fermentable dietary fibers. In: Reinhart, G. A., Carey, D. P. (eds.) *Recent Advances in Canine and Feline Nutrition*. Vol II. Wilmington: Orange Frazer Press, 1998: 113–122.

29. Nelson, R. W., Sunvold, G. D. Effect of carboxymethylcellulose on postprandial glycaemic response in healthy dogs. In: Reinhart, G. A., Carey, D. P. (eds.) *Recent Advances in Canine and Feline Nutrition*. Vol II. Wilmington: Orange Frazer Press, 1998: 97–102.

30. Blaxter, A. C., Cripps, P. J., Gruffydd-Jones, T. J. Dietary fibre and post prandial hyperglycaemia in normal and diabetic dogs. *Journal of Small Animal Practice* 1990; **31**: 229–233.

31. Graham, P. A., Maskell, I. E., Nash, A. S. Canned high fiber diet and postprandial glycemia in dogs with naturally occurring diabetes mellitus. *Journal of Nutrition* 1994; **124**: 2712S–2715S.

32. Nelson, R. W., Scott-Montcrieff, C., DeVries, S., Davenport, D., Neal, L. Effect of dietary insoluble fiber on control of glycaemia in dogs with naturally acquired diabetes mellitus. *Journal of the American Veterinary Medical Association* 1998; **212**: 380–386.

33. Stamler, J., Vaccaro, O., Neaton, J. D., Wentworth, D. Diabetes, other risk factors, and 12-yr cardiovascular mortality for men screened in the Multiple Risk Factor Intervention trial. *Diabetes Care* 1993; **16**: 434–444.

34. Schlotthauer, C. F., Millar, J. A. S. Diabetes mellitus in dogs and cats. *Journal of the American Veterinary Medical Association* 1951; **118**: 31–35.

35. Dixon, J. B., Sanford, J. Pathological features of spontaneous canine diabetes mellitus. *Journal of Comparative Pathology* 1962; **72**: 153–167.

36. Cotton, R. B., Cornelius, L. M., Theran, P. Diabetes mellitus in the dog: A clinicopathologic study. *Journal of the American Veterinary Medical Association* 1971; **159**: 863–870.

37. Anderson, N. V., Strafuss, A. C. Pancreatic disease in dogs and cats. *Journal of the American Veterinary Medical Association* 1971; **159**: 885–891.

38. Haines, D. M., Penhale, W. J. Autoantibodies to pancreatic islet cells in canine diabetes mellitus. *Veterinary Immunology and Immunopathology* 1985; **8**: 149–156.

39. Haines, D. M. A re-examination of islet cell cytoplasmic antibodies in diabetic dogs. *Veterinary Immunology and Immunopathology* 1986; **11**: 225–233.

40. Hess, R. S., Saunders, H. M., Van Winkle, T. J., Ward, C. R. Evaluation of concurrent disorders in dogs with diabetes mellitus (abstract). In: *Proceedings of the 17th Forum of the American College of Veterinary Internal Medicine*. Chicago, USA, 1999: 710.

41. Williams, D. A. Diagnosis and management of pancreatitis. *Journal of Small Animal Practice* 1994; **35**: 445–454.

42. Wiberg, M. E., Nurmi, A.-K., Westermarck, E. Serum trypsin like immunoreactivity measurement for the diagnosis of subclinical exocrine pancreatic insufficiency. *Journal of Veterinary Internal Medicine* 1999; **13**: 426–432.

43. Struble, A. L., Feldman, E. C., Nelson, R. W., Kass, P. H. Systemic hypertension and proteinuria in dogs with diabetes mellitus. *Journal of the American Veterinary Medical Association* 1998; **213**: 822–825.

44. Holste, L. C., Nelson, R. W., Feldman, E. C., Bottoms, G. D. Effect of dry, soft moist, and canned dog foods on postprandial blood glucose and insulin concentrations in healthy dogs. *American Journal of Veterinary Research* 1989; **50**: 984–989.

45. Sunvold, G. D., Bouchard, G. F. The glycaemic response to dietary starch. In: Reinhart, G. A., Carey, D. P. (eds.) *Recent Advances in Canine and Feline Nutrition*. Vol II. Wilmington: Orange Frazer Press, 1998: 123–131.

46. Liljeberg, H. G., Granfeldt, Y. E., Bjorck, I. M. Products based on a high fiber barley genotype, but not on common barley and oats, lower postprandial glucose and insulin responses in healthy humans. *Journal of Nutrition* 1996; **126**: 458–466.

47. Jarvi, A.E., Karlstrom, B. E., Granfeldt, Y.E., Bjorck, I. M., Vessby, B. O., Asp, N. G. The influence of food structure on postprandial metabolism in patients with non-insulin-dependent diabetes mellitus. *American Journal of Clinical Nutrition* 1995; **61**: 837–842.

48. Spears, J. W., Brown, T. T., Sunvold, G. D., Hayek, M. G. Influence of chromium on glucose metabolism and insulin sensitivity. In: Reinhart, G. A., Carey, D.P. (eds.) *Recent Advances in Canine and Feline Nutrition, Vol II. 1998 Iams nutrition symposium proceedings*. Wilmington: Orange Frazer Press, 1998: 103–113.

49. Anderson, R. A. Chromium, glucose intolerance and diabetes. *Journal of the American College of Nutrition* 1998; **17**: 548–555.

50. Anderson, R. A. Chromium, glucose tolerance, and diabetes. *Biological Trace Element Research* 1992; **32**: 19–24.

51. Ravina, A., Slezak, L., Rubal, A., Mirsky, N. Clinical use of the trace element chromium (III) in the treatment of diabetes mellitus. *Journal of Trace Elements in Experimental Medicine* 1995; **8**: 183–190.

52. Fox, G. N., Sabovic, Z. Chromium picolinate supplementation for diabetes mellitus. *Journal of Family Practice* 1998; **46**: 83–86.

53. Graham, P. A., Nash A. S. Survival data analysis applied to canine diabetes mellitus (abstract). In: *15th Annual Forum of the American College of Veterinary Internal Medicine*. Lake Buena Vista, USA. 1997: 689.

54. Forrester, S. D., Troy, G. C., Dalton, N., Huffman, J. W., Holtzman, G. Retrospective evaluation of urinary tract infection in 42 dogs with hyperadrenocorticism or diabetes mellitus or both. *Journal of Veterinary Internal Medicine* 1999; **13**: 557–560.

55. Bagley, L. H. II, Lavach, J. D. Comparison of postoperative phacoemulsification results in dogs with and without diabetes mellitus: 153 cases (1991–1992). *Journal of the American Veterinary Medical Association* 1994; **205**: 1165–1169.

56. Graham, P. A., Nash, A. S., McKellar, Q. A. Pharmacokinetics of a porcine insulin zinc suspension in diabetic dogs. *Journal of Small Animal Practice* 1997; **38**: 434–438.