DIETARY TREATMENT OF EPILEPSY

PRACTICAL IMPLEMENTATION OF KETOGENIC THERAPY

EDITED BY
ELIZABETH NEAL

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Dietary Treatment of Epilepsy

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Practical Implementation of Ketogenic Therapy

Edited by

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The therapeutic diets that are described in this book require specialist medical and dietetic supervision, and their success is dependent on a multidisciplinary approach to the patient's care. Dietary treatments must be individually prescribed and should not be initiated without the support of a dietitian and a neurologist or doctor with a special interest in epilepsy. Patients, parents or carers should not make any changes to their diet treatment without consulting an appropriate member of their diet team.

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Note to readers

The therapeutic diets that are described in this book require specialist medical and dietetic supervision, and their success is dependent on a multidisciplinary approach to the patient's care. Dietary treatments must be individually prescribed and should not be initiated without the support of a dietitian and a neurologist or doctor with a special interest in epilepsy. Patients, parents or carers should not make any changes to their diet treatment without consulting an appropriate member of their diet team.

Foreword

It gives me great pleasure to write a foreword for *Dietary Treatment of Epilepsy: Practical Implementation of Ketogenic Therapy*. This is a comprehensive book which includes much more than its title may suggest. The book fulfils two functions: it gives extensive and current evidence for the efficacy of the ketogenic regimen and also provides the know-how for healthcare professionals to safely implement and manage the diet. There is an impressive list of international contributors who are expert in their fields and the whole has been skilfully assembled by the editor so that it has a uniform style, a logical progression and is easy to read.

The book is divided into three sections. Section 1 reviews the science behind ketogenic therapies. The ketogenic diet has been slow to be accepted by healthcare professionals, particularly in the modern era of "miracle" and "celebrity" diets. Although it is not known exactly how the ketogenic diet works, the biochemistry of several possible mechanisms is explained, referring the reader to more detailed texts where appropriate. Sufficient evidence on the efficacy of diets is presented from renowned peer reviewed literature to satisfy and convince even the most sceptical.

The second section is perhaps the heart of the book as it covers in detail the practical aspects of ketogenic regimens. Every aspect of initiation, monitoring, nutritional adequacy, problems and discontinuation of the different diets is dealt with. A unique and insightful chapter is written by a parent; this should be essential reading for all who deal with children with epilepsy.

Section 3 extends the scope of the book by reviewing the use of ketogenic regimens in countries other than western economies; since 80% of people with epilepsy live in low or middle income countries this is relevant to a wide audience. The section continues by discussing the use of ketogenic diets in infants, in adults and in conditions other than epilepsy.

This book is not only for experienced dietitians (who will certainly learn from the wealth of experience of the contributors) but for other healthcare professionals including doctors, nurses, pharmacists, biochemists and anyone involved in the care of adults and children in the hospital or in the community. I am sure that this is the first of many editions of this book and that *Dietary Treatment of Epilepsy* will be the reference book on the subject for the foreseeable future.

Margaret Lawson MSc, PhD, FBDA
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A personal note

It's impossible to put into words what it feels like when you first witness your baby having a seizure – quite simply you think they are going to die. On that fateful evening I remember holding Matthew praying that he wouldn't be taken away from me as I waited for the ambulance to arrive. Little did I know that my life had just changed forever and although Matthew obviously didn't die, everything for his 'normal' future just had. My realization of that fact was going to be a long, painful and drawn-out process, as year by year I was going to witness Matthew have thousands upon thousands of seizures and more of my boy being taken away from me. It got to the stage where, once again, I would be holding him waiting for the ambulance to arrive, only this time I would be praying that he *would* die as I couldn't bear to watch his little body go through any more or listen to his screams as yet another seizure took hold of him.

I never knew about complex epilepsy. Like most of the population, I thought people with epilepsy just took medication and then they didn't have seizures any more. How naive of me. I was giving Matthew medication after medication and nothing was working. The doctor would come out with the following favourite phrases: 'just put the dose up further', 'we will add in another one' and 'we will get the right one eventually' – the 'right' medication never did turn up and every time hopes were raised and dashed and Matthew's personality had changed. His behaviour became very difficult to manage, and depending on the type of medication he was taking, at times violent and sleep-disturbed. Some of the drug 'treatments' even made the seizures worse, so you start looking for answers yourself and that is when I found the ketogenic diet.

The ketogenic diet offers something else; it offers another hope and sometimes a little hope is all we have left. When I first enquired about the ketogenic diet I was told that it was 'rubbish', that it 'didn't work' and that it was 'unpalatable and disgusting'. I believed the doctor that told me this and I rue the day that I did. Six years of asking for the diet and being refused it, until eventually when there was nothing left to try, Matthew was allowed to go on the ketogenic diet, thanks to the clinical trial that was being held at UCL-Institute of Child Health and Great Ormond Street Hospital. Within 2 weeks Matthew's seizures had reduced by 90%, he was bright, happy and relaxed and just a totally different boy; within 8 months of starting the diet he was off all medication and I got what was left of

my son back. As for the diet, it wasn't disgusting, it wasn't difficult and it wasn't unpalatable. I did have to be organized and it did take up a little extra time, but once I got used to it and got myself into a routine we were away. It felt *so good* to be doing something positive in the treatment of Matthew instead of just giving him pills that made him worse. Matthew was enjoying his food as he had always done and our family life as a whole was completely different. We actually had a life and I had the chance to enjoy time with my daughter Alice.

Matthew's story is now quite well known in the ketogenic world thanks to the charity I set up in his honour. I knew that other people would be going through the same heartache that I had been through and I wanted to make sure that the correct information was available for families as well as support for them, hence Matthew's Friends was born. No one wanted to be his friend when he was younger, his epilepsy was just too frightening, but today he has friends all over the world.

To see the diet now growing in popularity, to see more children benefiting and now adults too, I am delighted to be writing for this book which will hopefully help other medical professionals to work with these diets, so giving patients a better chance at a good quality of life. For some of them it will provide the ultimate miracle of complete seizure freedom for the rest of their lives. These diets should not be the last resort.

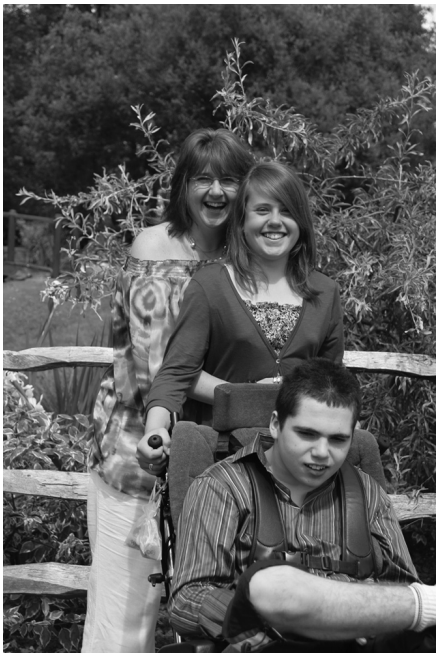
Even today I attend seminars where I hear professionals say that ketogenic dietary therapy is difficult to do and requires a 'complete lifestyle change for the family'. Although I hasten to add this is not true, it always makes me smile because what they need to realize is that we have already been through the biggest lifestyle change you could ever imagine by living with uncontrolled complex epilepsy and all the struggles that entails. Changing a diet around is nothing compared to that. My lifestyle completely changed after that first seizure. We need to remind the families of just how far they have come and encourage them, not frighten them.

2012 now sees Matthew enter his 18th year and we are looking forward to celebrating a birthday that we never thought he would make. Matthew has been off the diet for nearly 5 years and the good effects are still with us. Matthew is a bright, happy and totally chilled-out young man with a great quality of life. He and his sister have an exceptional relationship and they are both my proudest achievement. When Matthew smiles at me every morning then I know everything is right in my world.

I could not finish this without thanking Professor Helen Cross, Dr Elizabeth Neal and Hannah Chaffe, the team at Great Ormond Street that looked after Matthew and I through his ketogenic diet treatment. A special word has to go to Matthew's dietitian, Elizabeth Neal; her kindness, understanding and support was incredible and we all worked together to make Matthew as well as he could be. I can never thank her enough and neither can Matthew. Thank you also to all the professionals that work or want to work in this field. We cannot do it without you and by choosing to work in ketogenic dietary therapy you are going to be

making a huge difference to families that have already had hopes dashed and probably already been to hell and back. My promise to you is that the Matthew's Friends charity will continue to support you and the families as much as we can.

Emma Williams
Founder/CEO Matthew's Friends Global Charity,
Director Matthew's Friends Clinics



Emma, Alice (aged 15) and Matthew (aged 17)

Emma and Matthew

Section 1

Introduction and Overview

Chapter 1

Introduction to the ketogenic diet and other dietary treatments

Elizabeth Neal

Matthew's Friends Charity and Clinics, Lingfield, UK

Historical overview

The idea that inclusion or abstinence from certain foods could have benefits for those with seizures has origins that far precede our current era of scientific research. A dietary approach to the treatment of epilepsy can be traced back to the 5th century BC, when Hippocrates described a man whose seizures were cured by abstaining from all food and drink. Guelpa and Marie (1911) are accredited with writing the first scientific account of the benefits of fasting in epilepsy. In 1921 Geyelin also reported the successful use of fasting, with 20 of 26 fasted patients showing improved seizure control, two remaining seizure-free for over a year. The arbitrary length of fasting was 20 days, although only four had seizures after the tenth day without food (Geyelin, 1921). Geyelin was inspired by the work of Conklin, an osteopath who believed that epilepsy was caused by the release of a toxin from the Peyer's patches of the intestine which was taken up by the lymphatic system and periodically released into the blood, triggering seizures. Conklin therefore advocated complete gut rest and starved his patients for up to 25 days. He reported a 90 % success rate in children under the age of 10 years, decreasing to 50 % in those aged 25–40 years; success was more limited in the older adults (Conklin, 1922). These observations sparked considerable clinical and research interest, and linked with ongoing studies examining ketoacidosis and the disturbance in glucose metabolism that occurs in diabetes.

During starvation, the body passes through various phases of metabolic adaptation to spare muscle protein breakdown and draw on the energy reserves of body fat. Skeletal muscle and other tissues progressively switch energy source from glucose to free fatty acids generated from triglyceride breakdown. There is increased oxidation of fatty acids in the liver, with increased production of the water-soluble ketone bodies acetoacetate and β-hydroxybutyrate. Ketone bodies

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can be used as an alternative fuel by many tissues, most notably the brain, as unlike fatty acids they are able to pass across the blood–brain barrier. Blood ketone-body levels will continue to increase during the first 3 weeks of starvation during which the brain adapts to them as its primary energy source. (See Chapter 5 for further detail on biochemical changes and their connection with our current understanding of how dietary treatments may work.)

Prolonged starvation as a means to treat epilepsy had obvious practical limitations, and it was first suggested by Wilder (1921a) that a diet very high in fat and low in carbohydrate might mimic the benefits of fasting by causing a similar ketotic effect. He tried this proposed 'ketogenic diet' (KD) on three of his patients at the Mayo Clinic and reported significant seizure control (Wilder, 1921b). Peterman, a fellow worker at the clinic, reported further successful results in children treated with this KD (Peterman, 1924). Talbot and his co-workers introduced the idea of a preliminary fast before commencing the diet, with a gradual build-up of dietary fat over the following few days. His clear instructions on how to calculate the diet form the basis of the classical KD calculations used widely today (Talbot et al., 1927; Talbot, 1930; see Chapter 8).

Other early studies also reported the wide use and success of the KD (Helmholz, 1927; McQuarrie and Keith, 1927; Lennox, 1928; Wilkins, 1937). The discovery of new anticonvulsant drugs at the end of the 1930s distracted clinical and research interest from diet and towards medications, the latter perceived to be both simpler and more palatable to use. Increasing realization that not all seizures respond to drugs and concerns about medication side effects and the possible ramifications of prolonged intractable seizures, especially in the context of childhood development, have renewed interest in dietary treatments. The past few decades have seen a steady proliferation of published research, accompanied by a broadening of clinical application extending beyond the traditional classical form of KD. While this is still used extensively today, alternative types of KD therapy have allowed a more flexible approach to dietary treatments for epilepsy.

The classical and medium-chain triglyceride KD

Early studies in children by Wilder, Peterman and Talbot used a diet of 1 g protein per kilogram body weight, with 10–15 g carbohydrate daily, the remaining energy supply being from fat. Fat was primarily animal based, in the form of butter, lard and cream. The term 'ketogenic ratio' was used to describe the ratio of ketone-producing foods in the diet (fat) to foods that reduced ketone production (carbohydrate and protein). Seizure control was found to be optimal with a ratio of 3 or more. This led to the terminology of a 3 : 1 KD (87 % of total dietary energy derived from fat) or 4 : 1 KD (90 % of total dietary energy derived from fat). This is the basis of the classical KD used today. Carbohydrate intake is very limited: bread, cereals, pasta or rice are generally not allowed, the main carbohydrate sources being controlled portions of vegetables or fruit at each meal. Protein is

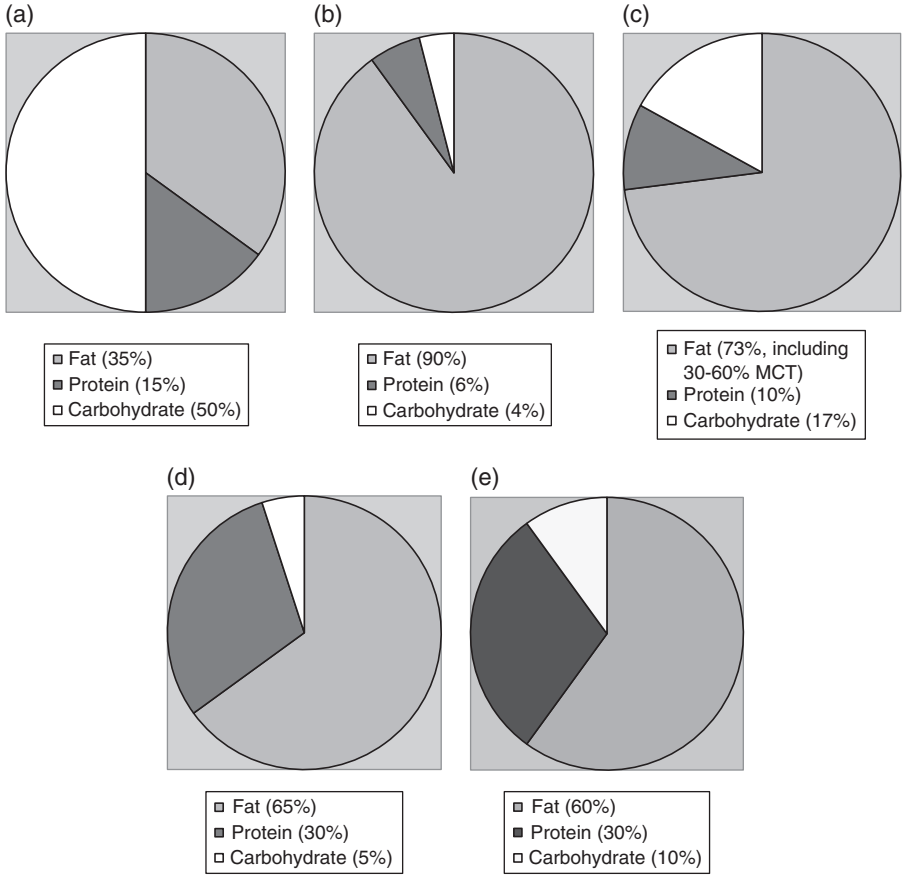

Figure 1.1 The composition of ketogenic diet treatments: approximate percentages of dietary energy from fat, protein and carbohydrate. (a) Recommended UK diet; (b) classical 4 : 1 ratio ketogenic diet; (c) MCT ketogenic diet; (d) modified Atkins diet (at 1 : 1 ketogenic ratio); (e) low glycaemic index treatment.

kept to a minimum to meet requirements: a source can be included at each meal, such as meat, fish, egg or cheese, but protein foods that contain additional sources of carbohydrate are generally avoided. The macronutrient composition of this type of diet is substantially different from an average UK diet (Figure 1.1).

A modification of the classical KD was proposed in 1971, using medium-chain triglyceride (MCT) as an alternative fat source (Huttenlocher et al., 1971). The main constituents of MCT are the medium-chain octanoic and decanoic fatty acids, which are absorbed more efficiently than their long-chain counterparts, and which are carried to the liver in portal blood bound to albumin. This is in contrast to long-chain fatty acids, which are incorporated into chylomicrons and transported via the thoracic duct through the lymph system, exiting into the circulation at the left subclavian vein from where they are carried via peripheral

tissues to the liver. After hepatic tissue uptake, medium-chain fatty acids can pass directly into liver mitochondria for subsequent oxidation and ketone body synthesis. Long-chain fatty acids require carnitine for their transport across this mitochondrial membrane. These differences in MCT metabolism facilitate a more rapid and greater oxidation of medium-chain fatty acids, resulting in a higher ketone yield per kilocalorie of dietary energy than that from long-chain fat. Therefore less total fat is needed in the diet to achieve the desired level of ketosis. More protein and carbohydrate can be allowed with the aim of improving palatability and patient acceptance.

Huttenlocher went on to show that a KD providing 60 % of total dietary energy from MCT was as effective as a 3 : 1 classical diet in producing ketosis and controlling seizures in 12 children with epilepsy (Huttenlocher, 1976). This amount of ingested MCT, particularly if introduced too quickly, can cause gastrointestinal side effects, primarily diarrhoea and abdominal discomfort. Although these can be ameliorated with dietary adjustment, in some individuals a more moderate prescription may be appropriate. Schwartz and her colleagues suggested a modified MCT diet, providing 30 % of dietary energy from MCT and an extra 30 % from long-chain fats such as butter or cream; this has been termed the John Radcliffe diet. They also reported no difference between the classical, MCT and modified MCT KDs in controlling seizures in a non-randomized study (Schwartz et al., 1989). A more recent randomized trial by our group also showed neither the classical nor MCT KD to be superior when assessing efficacy or tolerability after 3, 6 or 12 months of treatment (Neal et al., 2009). Further details on the classical and MCT KD can be found in Chapters 8 and 9.

Alternative KD therapies

In the last decade two other types of KD therapy have been used with success. The modified Atkins diet (MAD) was first used in 2002 for two children at the Johns Hopkins Hospital in Baltimore, USA. One child was waiting for a scheduled admission to start the classical KD; another had discontinued classical KD a year before. Seizures were successfully controlled with the MAD in both cases (Kossoff et al., 2003). This diet restricts carbohydrates, encourages high-fat foods, but does not limit or measure protein or total calories. The principles are based on the popular weight loss diet first described by Dr Robert C. Atkins in 1972 (Atkins, 1972), with the primary outcome goal of weight loss replaced by one of seizure control. Carbohydrate is usually restricted to 10–20 g per day and review of dietary records shows that the approximate ratio of fat to carbohydrate and protein is 1 : 1 compared with 3 : 1 or 4 : 1 with the classical KD. There is a growing body of scientific publications reporting successful use of the MAD.

An alternative diet, the low glycaemic index treatment (LGIT), was first described in 2005 (Pfeifer and Thiele, 2005). This diet restricts carbohydrates to 40–60 g per day but only allows those with a glycaemic index of less than 50, the

aim being to minimize increases in blood glucose. Food is not weighed but based on portion sizes. Protein, fat and calorie intake is loosely monitored, albeit considerably less strictly than on traditional KDs. Unlike the MAD, a high-fat intake is not actively encouraged.

Figure 1.1 illustrates the differences in dietary composition of these alternative dietary treatments as compared with traditional KDs. Because of the flexible nature of the MAD and LGIT, the percentages of energy from the different macronutrients may vary between individual diets; the figures chosen give the reader some idea of how an average diet might look. Further details on the MAD and LGIT can be found in Chapters 10 and 11.

Other non-KD treatments

There have been suggestions that food intolerance could be linked to epilepsy in the literature, although these are mostly anecdotal and uncontrolled reports. A 1968 review of 26 studies examining a relationship between epilepsy and allergies concluded that pollen, dust and moulds were the main culprits (Fein and Kamin, 1968). In a study examining the role of oligoantigenic diets in 63 children with epilepsy, 45 of whom had associated headaches, abdominal symptoms or hyperkinetic behaviour, 37 had improved seizures on an elimination diet (Egger et al., 1989). However, the 18 children with epilepsy alone showed no improvement. A further study of the same elimination diet failed to demonstrate any benefit in nine children with epilepsy (Van Someren et al., 1990). Although it is possible that allergic reactions could trigger seizures in susceptible patients, the present evidence does not support the use of elimination diets in epilepsy treatment and further detail on this type of dietary therapy is not included in this book.

Application and availability of KD therapy

The classical and MCT KDs are primarily used in children, although studies have demonstrated benefit in infants (Nordli et al., 2001; Hong et al., 2010), adolescents (Mady et al., 2003) and adults (Sirven et al., 1999); the MAD has also been demonstrated effective in treating adults (Kossoff et al., 2008a). The flexible protocols employed in both the MAD and LGIT are clearly useful for adolescents and adults with epilepsy who may prefer a less rigid dietary treatment, but they can also be used with success as an alternative for children. Although most of this book will refer to children, a separate chapter on adults is also included. As well as being successfully used to treat epilepsy in all age groups, the KD is an important treatment for two metabolic disorders, glucose transporter (GLUT)-1 deficiency and pyruvate dehydrogenase deficiency (see Chapter 27).

Worldwide use of the KD has increased dramatically since the early 1990s. Although the greatest number of centres offering this treatment are in the USA,

a survey reported KD programmes in 41 other countries, 16 of which had multiple centres (Kossoff and McGrogan, 2005). Most geographic regions were represented, with the exception of the majority of Africa and Central America. Most of the larger centres in the USA used a classical KD protocol at the time of this survey, but European and worldwide KD practice was more varied, with both classical and MCT diets being employed. Both protocols are used within the UK; a postal survey of 280 British Dietetic Association Paediatric Group members in 2000 found 22 centres were using the KD, 13 the classical and nine the MCT (Magrath et al., 2000). The survey was repeated in 2007 and although use of the KD had risen by 50 %, numbers were still small as this only represented an increase of 51 patients (Lord and Magrath, 2010). At the time of this survey, no dietitians reported using MAD or LGIT. Similar to reports from other European centres (Kossoff and McGrogan, 2005), a lack of funding resources and dietetic time was identified as the main barrier to greater use of dietary treatments. Since these studies were published, practice has changed considerably, with many more centres in the UK and around the world now using the MAD, and a smaller but growing number the LGIT. Using MAD as a dietary treatment for epilepsy in developing countries is also being explored (Kossoff et al., 2008b). Neurologists are becoming more aware of dietary therapies, but many continue to reserve its use until a child has failed a number of anticonvulsants.

The successful use of more relaxed KD therapies is leading the way towards a flexible, rather than rigid, approach to dietary treatment of epilepsy; this may include components of the various protocols drawn together to provide a treatment individually tailored to specific dietary and lifestyle requirements. A clear understanding of how the different types of diet are calculated and implemented is essential before they can be adapted in such a way and this book aims to provide the information to help foster this understanding. The inclusion of guidance on when to use KD therapy, how to initiate, calculate, fine-tune, monitor and discontinue treatments, the potential side effects, use in infants and adults as well as children, and practical advice from both parent and dietitian, will provide readers with a comprehensive and practical training on all aspects of implementation.

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Chapter 2

Epilepsy and epileptic seizures

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Epilepsy is a diagnosis given when an individual is prone to recurrent epileptic seizures. By definition an epileptic seizure is a change in movement or behaviour that is the direct result of a primary change in the electrical activity of the brain. Up to 1 in 20 individuals will have an epileptic seizure in their lifetime; only 1 in 200 will experience more than two seizures and therefore be given a diagnosis of epilepsy. Epilepsy is a symptom and there are many different causes; it would be more accurate to term the condition 'the epilepsies'. Moreover, there is no single diagnostic test. Diagnosis is made on the assessment of description of events by experienced physicians with support from results of investigations. Prognosis will depend on the type and cause of the epilepsy; further decisions about management and need and type of treatment will also be dependent on the underlying diagnosis and type of epilepsy.

Diagnosis

An epileptic seizure can be defined as an intermittent and stereotyped disturbance of consciousness, behaviour, emotion, motor function or sensation that on clinical grounds is believed to result from cortical neuronal discharge, determined as a change in the electrical activity of the brain. Epilepsy is defined as a condition in which unprovoked (namely not triggered by an acute condition) seizures recur, usually spontaneously. Consequently, by definition, an individual is diagnosed as having epilepsy if he or she has had at least two epileptic seizures. Diagnosis can be challenging. As there remains no diagnostic test, a diagnosis should be made by a physician with an expertise in epilepsy, in the case of children by a paediatrician, as the diagnosis will be made on the basis of description of events by an eyewitness. Events suggestive of epileptic seizures may occur as the result of a

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Box 2.1 Differential diagnosis for epilepsy in children.

Syncope and related disorders
Disorders of orthostatic control: reflex syncope
Respiratory syncope
  Reflex and expiratory apnoeic syncope
  'Fainting lark'
  Upper airway obstruction
Cardiac syncope
  Arrhythmias
  Complete heart block
  Wolf–Parkinson–White syndrome
Brainstem syncope
  Tumour
  Brainstem herniation or compression
Other: anoxic epileptic seizures

Neurological
Tics
Myoclonus
Paroxysmal dystonia
Sandifer syndrome
Paroxysmal dyskinesias
Cataplexy
Benign paroxysmal vertigo/torticollis
Migraine
Alternating hemiplegia
Eye movement disorders
Overflow movements
Hyperekplexia

Behavioural/psychiatric
Daydreams
Dissociative states
Self-gratification behaviour
Hyperventilation
Panic/anxiety
Non-epileptic attack disorder
Fabricated attacks
Pseudosyncope
Stereotypies/ritualistic behaviour

Sleep disorders
Sleep myoclonus
Headbanging
Confusional arousal
REM sleep disorder/night terrors

secondary change to the electrical activity of the brain, for example the result of other causes of collapse such as syncope or heart arrhythmias. The range of differential diagnosis is particularly wide in children (Box 2.1). The misdiagnosis rate is consequently high; up to 40% of children attending a tertiary clinic for an opinion for epilepsy may subsequently prove not to have the condition.