NEUROMUSCULAR DISEASE AND ANAESTHESIA

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Diseases affecting the neuromuscular system are numerous and not uncommon (for classification see Appendix). Almost all of the drugs used in anaesthesia have either a direct or an indirect effect on muscle, and so an understanding by anaesthetists of the neuromuscular diseases is essential in view of the universal requirement of muscle relaxation during surgery. The intention of this article is not to help anaesthetists to diagnose and to treat peripheral neurological disease, but to alert them to some of the dangers of anaesthesia in these affected patients.

Anaesthesia is often requested for patients who are suspected of having neurological disease but for whom a definite diagnosis is either impossible or provisional; or anaesthesia may be required to investigate or treat an unrelated illness. A definite diagnosis is the exception, and it is intended to present this subject from the viewpoint of the anaesthetist who is questioning preoperatively whether a patient with a suspected neuromuscular disease may present problems which can be avoided or anticipated. The first section deals with specific difficulties which have been encountered during anaesthesia in association with neuromuscular disease, while the second section contains suggestions for preoperative assessment.

SPECIFIC PROBLEMS

Potassium imbalance.

(a) Hyperkalaemia. The dangers of hyperkalaemia in the anaesthetized patient are well known, the most important effects being on the heart (Roth and Wüthrich, 1969; Vaughan and Lunn, 1973). Acute hyperkalaemia results from an efflux of intracellular potassium, and as muscle accounts for most of the total body potassium, disorders of muscle can be responsible for rapid changes in extracellular potassium. Even in normal patients, membrane-active drugs such as the depolarizing relaxants have been shown to cause a short-lived rise in extracellular potassium (Paton, 1956; Klupp and Kraup, 1954), which is increased if muscle activity is stimulated by e.c.t. (Haw, 1972) or if halothane is used subse-
m.mol/l. (Kendig, Bunker and Endow, 1972); similar results have been obtained in man (Tobey et al., 1972).

Three forms of familial periodic paralysis have been described, depending on whether the serum potassium is low, normal or high. In the hyperkalaemic variety, quite modest increases in serum potassium produce severe muscular weakness. An exacerbation of muscular weakness can occur with cold, which causes hyperkalaemia in these patients, and the patient notices weakness and increased tone in the face in cold weather, or in the pharynx when eating ice cream (McArdle, 1969). The usual fall in body temperature accompanying anaesthesia could constitute a stress sufficient to induce hyperkalaemia and muscle weakness.

Severe and sometimes fatal hyperkalaemia occurs with malignant hyperpyrexia, which has been shown to be associated with muscle disease (Harriman, Sumner and Ellis, 1973).

(b) Hypokalaemia. Apart from the hypokalaemic type of familial periodic paralysis mentioned above, hypokalaemia can occur in myasthenia gravis; thus, one of the adjuncts to therapy is potassium. Uncorrected hypokalaemia would increase the sensitivity of myasthenics to non-depolarizing muscle relaxants.

Myoglobinuria.

When muscle cells become damaged or necrotic, myoglobin is released. Myoglobin, with a molecular weight of 17,000, has a low enough renal threshold to be filtered by the glomerulus. It is recognizable in the urine as a brown pigment; both spectrophotometric and chemical tests (o-toluidine reaction) can be used for confirmation. The danger from myoglobinuria is renal tubular obstruction due to casts of myoglobin in the distal tubules, which is especially likely to occur if the urine is acidic.

Myoglobinuria is not often seen in association with chronic muscle disease. However, it has been described as a complication of muscle trauma and ischaemia, such as the crush injuries in the air raids of the Second World War (Bywaters et al., 1941). Acute exacerbations of paroxysmal myoglobinuria (or acute paroxysmal rhabdomyolysis), which can be induced by stress, fever and alcohol (Humphrey, 1973), can cause heavy myoglobinuria. Myoglobinuria has been described in disorders of muscle energy metabolism such as McArdle’s disease (McArdle, 1951), severe acute polymyositis, and in association with certain toxic chemicals such as alcohol (Hed et al., 1962), carbon monoxide and barbiturates (Fahlgren, Hed and Lundmark, 1957).

Drugs used in anaesthesia can be added to the list of toxic chemicals capable of producing myoglobinuria. In 1964, Bennike and Jarnum reported a 29-year-old male with a muscle condition affecting both thighs, who developed myoglobinuria and renal failure after an anaesthetic involving suxamethonium and halothane. No hyperkalaemia was detected, but there was a marked elevation in the serum levels of the muscle enzymes creatine phosphokinase, the transaminases and lactic dehydrogenase. Muscle biopsy showed muscle necrosis, and the authors stated that at least 200 g of muscle had to become necrotic before myoglobinuria could be recognized. Their patient suffered from idiopathic myoglobinuria, which can be precipitated by exercise, alcohol and barbiturates; they likened the effects of the marked fasciculations following suxamethonium to vigorous exercise.

Airaksinen and Tammisto (1966), using a very sensitive precipitation test for myoglobin, reported that 7 of 24 ophthalmic patients having surgery for correction of squint developed myoglobinuria postoperatively; many patients with squint have a myopathy. Although they incriminated suxamethonium, no patient developed myoglobinuria who did not receive halothane as well. Thus, it seemed that the common association of suxamethonium and halothane has a more powerful rhabdomyolytic action on susceptible patients than either drug separately. A further case was reported by McLaren (1968), and again suxamethonium was implicated. In this case suxamethonium did not cause relaxation of skeletal muscle, but induced myotonia. It is probable that the prior administration of tubocurarine would inhibit some of the undesirable effects of suxamethonium (Tammisto, Leikkonen and Airaksinen, 1967).

Myoglobinuria and renal failure are being reported more frequently as a late complication of malignant hyperpyrexia (Wade, 1973; Ellis, 1973) in which muscle diseases have been detected (Britt et al., 1973; Harriman, Sumner and Ellis, 1973). In malignant hyperpyrexia, muscle breakdown can occur to an astonishing degree and patients have lost several kilograms of muscle following a short anaesthetic (Britt, 1971).

Myotonia.

Myotonia is the continued active contraction of a
muscle which persists after the cessation of voluntary effort or stimulation (Walton and Gardner-Medwin, 1969). The characteristic disorder is an inability of the affected muscles to relax. Although a degree of overlap occurs, the three classical diseases in which myotonia is a cardinal feature are dystrophia myotonica, myotonia congenita and paramyotonia congenita.

One problem for the anaesthetist in myotonia is the development of generalized muscle spasm with depolarizing muscle relaxants. Orndahl and Sten-berg (1962) investigated 13 patients with dystrophia myotonica and one with myotonia congenita, by recording the mechanical response of muscle following the administration of suxamethonium, succinyl monocholine and decamethonium. They found that all patients developed muscle spasm and a heightened sensitivity to all three depolarizing drugs. The induced myotonia was enhanced by anticholinesterases and diminished by non-depolarizing relaxants which, when given on their own, produced normal muscle relaxation. A tachyphylaxis was found with suxamethonium, and an analogy might be drawn with the beneficial effects of exercise in patients with clinical myotonia and increased end-plate activity with depolarizers. Orndahl and Sten-berg also found that a similar response to the depolarizing relaxants was found in patients suffering from denervation.

In clinical practice, the development of generalized muscle spasm with depolarizing relaxants can result in acute ventilatory failure due to restriction of movements of the thoracic cage (Paterson, 1962), although Kaufman (1960) stated that in dystrophia myotonica respiratory depression during anaesthesia was due to central depression. In his series of 25 patients with dystrophia myotonica, 1 of 4 who received suxamethonium developed muscle spasm. Kaufman observed that myotonia of the respiratory muscles could occur during ether or spinal anaesthesia as well as with the depolarizing relaxants.

Paterson (1962) described a patient with clinical myotonia who developed severe tonic muscular spasm after suxamethonium, which rendered passive inflation of the lungs impossible for 3½ min. The patient was exposed to suxamethonium on two further occasions, resulting in a similar alarming degree of tonic muscle spasm. No fasciculations were seen before the spasm developed. Further instances of a myotonic response to suxamethonium have been reported in patients with myotonia congenita (Thiel, 1967), myotonic dystrophy (Cody, 1968; Dalal et al., 1972), polymyositis (Davies, 1970) and denervation (Brim, 1973).

The subject of muscle spasm following suxamethonium has become more complex, because 70% of patients developing malignant hyperpyrexia have muscle spasm after either suxamethonium or one of the anaesthetic vapours (Britt and Kalow, 1970). Kalow and Britt (1973) have also suggested that atropine may be involved, as its use preoperatively is commoner in patients who develop early muscle spasm with hyperpyrexia. In an early report of hyperpyrexia by Saidman, Harvard and Eger (1964), myotonia congenita was implicated; however, since then malignant hyperpyrexia with muscle spasm has been shown to occur in a wide variety of neuromuscular diseases including central core myopathy (Denborough, 1973), Barnes myopathy (Steers, Tallack and Thompson, 1970), denervation (La Cour, Juul-Jensen and Reske-Nielsen, 1971), and malignant hyperpyrexia myopathy (Harriman, Sumner and Ellis, 1973).

Thiopentone was used by Davies (1966) in a patient with Huntington's chorea, and was thought responsible for prolonged apnoea and a slow recovery complicated by generalized tonic spasm of the musculature.

Cardiomyopathy.

The occurrence of cardiomyopathy with disease of skeletal muscle is a most important hazard of anaesthesia in this type of patient. Cardiac involvement is often unrecognized, and symptoms may be mild or absent because of the patient's inability to perform normal muscular exercise due to muscle weakness.

The cardiomyopathies are diseases of heart muscle of obscure aetiology (not coronary artery disease), which may affect both endocardium and pericardium. They can be classified into two broad categories, namely primary cardiomyopathy in which only the heart is involved, and secondary cardiomyopathy in which the heart disease is associated with a systemic disease. The primary cardiomyopathies are of three functional types: systolic pump failure (congestive), diastolic compliance failure (hypertrophic), and obliterative. Some of the secondary cardiomyopathies are classified in table I.

The muscle diseases which are associated with cardiomyopathy are fairly well documented, but it
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Table I. Cardiomyopathies of known cause or association (adapted from Oakley, 1972).

<table>
<thead>
<tr>
<th>Classification</th>
<th>Examples</th>
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<tbody>
<tr>
<td>Infective</td>
<td>viral myocarditis</td>
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<tr>
<td>Metabolic</td>
<td>thyroid states</td>
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<td>Endocrine</td>
<td>glycogen storage disease</td>
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<td>Familial</td>
<td>beri-beri</td>
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<td>Nutritional</td>
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<td>Amyloid</td>
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<td>Pregnancy</td>
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<td>Muscle disease</td>
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<tr>
<td>(a) classical muscular dystrophies and dystrophia myotonica</td>
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<tr>
<td>(b) neuronal dystrophies and Friedreich’s ataxia</td>
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<td>Collagen disease</td>
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<tr>
<td>Sensitivity phenomena</td>
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<tr>
<td>Toxic</td>
<td>arsenic, cobalt</td>
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<td>Heavy metals</td>
<td>alcohol, chloroform</td>
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<td>Anaesthetics</td>
<td>phenothiazines and tricyclic antidepressants</td>
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<td>Drugs</td>
<td>radiation</td>
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<td>Physical damage</td>
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<td>Senile</td>
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came as a surprise to realize that incipient cardiac failure was detectable in over half of a group of patients with pseudohypertrophic and limb girdle muscular dystrophies (Wahi, Bhargava and Mohindra, 1971; Coltart, 1972). In a prospective study, Perloff and colleagues (1966) found that cardiomyopathy was common in the pseudohypertrophic dystrophy (Duchenne), uncommon in the limb girdle dystrophies, and rare in the facioscapulohumeral dystrophy. The diagnosis depends on detecting atrial and third heart sounds, abnormalities in the electrocardiogram, and occasionally on obvious clinical cardiomegaly and abnormal cardiac outline on chest X-ray. The electrocardiogram has been specified in the progressive muscular dystrophies by Wahi and colleagues (1971), who include short PR interval, R/S ratio in V1 greater than 1.5, high amplitude R wave and deep Q wave in V4-6 and prolonged QTC; they call this the “myopathic pattern”. However, the e.c.g. changes were not invariably seen in patients with incipient cardiac failure (this being defined as an abnormal increase in right ventricular end-diastolic pressure either at rest, or after right hypochondrial compression). An important finding is that moderately severe cardiomyopathy can be present and yet the e.c.g. may be within normal limits. It would be wise to assume that all dystrophic children have myocardial involvement, and myocardial depressants should be avoided.

Apart from in these progressive muscle diseases, cardiomyopathy has been described in several other conditions. Alcoholic myopathy may be due to the toxic effects of alcohol, to additives to beer such as cobalt, or to vitamin deficiencies (Shanoff, 1972). Cardiomyopathy is found in association with thyroid myopathy, steroid myopathy, thiamine deficiency, glycogen storage disease (Perl, 1971), pregnancy and the puerperium (Stuart, 1968), and especially with Friedreich’s ataxia, in which 55% of patients have heart disease (Boyer, Chisholm and McKusick, 1962).

Death during induction of anaesthesia was seen by the author in a 2-year-old boy with glycogen storage disease (Pompe’s disease). An irreversible cardiac arrest occurred shortly after an uncomplicated induction with nitrous oxide, oxygen and halothane 1%. At postmortem the heart was grossly enlarged and both cardiac and skeletal muscle were severely infiltrated with glycogen. The anaesthetic vapours are no longer used in dystrophic patients.

Although signs of cardiomyopathy may be absent, it is not uncommon for anaesthetized dystrophic children to develop cardiac signs which must be considered ominous. Signs we have seen include a heaving left parasternal cardiac impulse, sudden tachycardia or dysrhythmias, and venous congestion. An e.c.g. taken at this time may show abnormalities such as right ventricular preponderance, Q waves, and altered T waves in the precordial leads.

Restrictive respiratory inadequacy.

Patients with neuromuscular disease may develop restrictive respiratory inadequacy for three reasons, namely weakness of respiratory muscles, skeletal abnormalities secondary to muscle disease, and induced myotonia (as mentioned previously). The precipitation of ventilatory failure by anaesthesia is quite understandable in patients with restricted ventilation. Postoperatively, patients have central respiratory depression due to narcotics and other respiratory depressants (Gillam et al., 1964), obstructive problems with sputum retention, bronchitis or bronchopneumonia (aggravated by a weak cough), and ventilatory restriction due to wound pain. The anaesthetic problems in the quadriplegic patient in whom restrictive respiratory failure occurs have been described by Quimby, Williams and Greifenstein (1973). Many neuromuscular diseases
are progressive, and restrictive ventilatory failure complicated by pneumonia is often the ultimate cause of death in myasthenia gravis, motor neurone disease, muscular dystrophy, and multiple sclerosis. Thus, the more incapacitated the patient the greater the danger of anaesthesia.

Tests of pulmonary ventilatory function, including tidal volume, minute ventilation, vital capacity, maximum breathing capacity and forced expiratory volume, revealed restrictive changes in over half of a group of patients with dystrophic involvement of the chest wall (Wahi, Bhargava and Mohindra, 1971). Littler, Reuben and Lane (1973) measured lung blood flow in 10 patients with scoliosis and in 6 with neuromuscular disease (poliomyelitis and dystrophy), and found that these patients had a decreased lung blood flow transit time resulting in arterial hypoxaemia. There was a linear correlation between pulmonary blood transit time and arterial oxygen tension. Scoliosis caused lung compression and increased the work of breathing, resulting in hypoxaemia, pulmonary hypertension and right heart failure.

The problem may arise particularly when mechanical ventilation is to be discontinued. Bendixen, Egbert and Hedley-Whyte (1965) have recommended that a patient should be capable of sustaining more than 20 cm H$_2$O negative pressure during voluntary inspiration, before an attempt is made to stop mechanical ventilation.

There is a continual danger, in the postoperative period, of acute restrictive failure in certain patients. The myasthenic patient recovering from thoracotomy (for thymectomy) may develop acute myasthenic or cholinergic crises. Wolfe, Sealy and Young (1972) recommend ventilator treatment for these patients for 2–4 days postoperatively to obviate this danger, and Crawford (1971) also mentions the need to ventilate some post-thymectomy myasthenics.

It is logical to test for restricted ventilation, using spirometry, before anaesthesia is undertaken in all obviously incapacitated patients with muscle disease. Blood gases should be measured preoperatively to establish a baseline. Postoperatively, a worsening blood gas picture or obvious ventilatory difficulty with dyspnoea or paradox should necessitate active treatment with IPPV, with or without tracheostomy.

Some patients with muscle involvement in systemic disease such as sarcoidosis, or one of the collagen diseases, have pulmonary infiltration which restricts ventilation.

**DISTURBANCES OF TEMPERATURE REGULATION**

**(A) Hyperthermia.**

The most fulminating and potentially lethal type of hyperthermia under anaesthesia is malignant hyperpyrexia, which has been shown commonly to be associated with muscle disease. The presence of primary muscle disease or myopathy was postulated by Isaacs and Barlow (1970), and there have been several investigations of the muscle pathology of patients who have recovered and of susceptible relatives. In most families the myopathy is mild or subclinical, and only rarely are there direct symptoms of muscle weakness. However, musculoskeletal abnormalities which are found in association with myopathy, such as squints, herniae and minor orthopaedic problems, are often found in affected families (Britt and Kalow, 1970). Steers, Tallack and Thompson (1970) described an affected family with a severe congenital myopathy, and Denborough (1973) has described a myopathy similar to central core disease. Harriman and associates (1973) believed that the myopathy differed from all previously described, and suggested that it should be called “malignant hyperpyrexia myopathy”. Britt et al. (1973), in an investigation of five patients, confirmed that the muscle showed changes consistent with latent myopathy.

The muscle from affected patients can be used to indicate susceptibility. Muscle contracture (spasm) occurs when certain anaesthetic drugs are administered to the muscle tissue in vitro (Ellis et al., 1972; Ellis and Harriman, 1973), and Kalow et al. (1970) have shown that malignant hyperpyrexia muscle is more sensitive to caffeine-induced rigor than normal muscle. Harrison et al. (1969) have demonstrated that susceptible porcine muscle becomes rapidly depleted of ATP in vitro when halothane is administered.

Whether malignant hyperpyrexia is a highly specific condition, or represents the extreme of a continuum of conditions, is not clear. For example, patients with osteogenesis imperfecta sometimes develop pyrexia during anaesthesia (Solomons and Myers, 1973), or postoperatively (Dale and Ellis, 1973). In one such patient, Harriman (1974) found a severe myopathy histologically. Ellis and Clarke (1974) have had three patients with progressive pseudohypertrophic dystrophy who developed marked pyrexia (39–40°C) within a few hours of uncomplicated anaesthesia. In only one of these patients was active cooling necessary. It is possible
that the difference between these patients and those with fulminating and progressive hyperpyrexia may be only one of degree.

(b) Hypothermia.

It has been frequently observed preoperatively (Ellis and Clarke, 1974) that patients with severe neuromuscular disability have muscle temperatures which are considerably less than body core temperature when measured directly with a needle thermistor probe. In healthy patients the temperature gradient between rectum and thigh is about 1°C, but in advanced muscle disease this may be 3–4°C. These observations are similar to those of Cannard and Zaimis (1959), who found that a normal gradient of 1–2°C was increased by immobilization of the limb. Thus, the lower temperature in muscle disease could be a reflection of inactivity.

It is accepted that when muscle is hypothermic there is an increased magnitude and duration of effect of depolarizing relaxants, and a reduced magnitude of neuromuscular block produced by tubocurarine (Maclagen and Zaimis, 1957; Brigland et al., 1958; Holmes, Jenden and Taylor, 1951; Cannard and Zaimis, 1959). The importance of these observations is threefold. Firstly, some of the "abnormal" responses to muscle relaxants seen in patients with muscle disease could be due to muscle hypothermia (which increases with anaesthesia). Secondly, the interpretation of the results of motor nerve stimulation as a diagnostic aid during anaesthesia would be marred if a hypothermic peripheral muscle is used to indicate the state of central muscles. Thirdly, in thoracic and upper abdominal surgery, the diaphragm cools (Wollmann and Cannard, 1960) and the dose of non-depolarizing relaxants may have to be increased. Muscle hypothermia results in slower muscle blood flow, and recovery from relaxants can be prolonged.

Hypothermia of muscle has been shown to reduce spasticity and clonus in patients with paraplegia and multiple sclerosis (Miglietta, 1973).

Miscellaneous problems.

There is some dispute as to whether exposure to general anaesthesia induces exacerbations in patients with multiple sclerosis. Baskett and Armstrong (1970) reported four patients in whom relapses had occurred postoperatively. Frost (1971), who reported multiple anaesthetics in three patients with multiple sclerosis, found no worsening of the condition. Most anaesthetists accept that spinal anaesthesia is inadvisable in any patient with a disease affecting the spinal cord. An exacerbation of acute demyelination in acute intermittent porphyria with barbiturates is well known, and these drugs must be avoided (Ward, 1965). Propanidid has been used in porphyria (Dean, 1969), although it has been demonstrated that propanidid has a significant effect on axons and causes a marked depression of axonal conduction during induction of anaesthesia (Ellis, 1971).

There have been reports of abnormal reactions to muscle relaxants in patients with von Recklinghausen's disease. Manser (1970) described two patients who developed prolonged paralysis after tubocurarine and suxamethonium respectively, and Magbagbeola (1970) reported prolonged apnoea in one patient after both suxamethonium and pancuronium. Baraka (1974) described a patient with von Recklinghausen's disease who was resistant to suxamethonium and unduly sensitive to tubocurarine. He suggested that these findings indicated a myasthenic response rather than just an effect of denervation.

Severe muscle-wasting predisposes to osteomalacia, and osteomalacia can cause uraemia, and also greatly weakened bones which may fracture with passive manipulation. Wasted muscle becomes fibrotic and in the absence of adequate physiotherapy, chronic muscle contractures develop resulting in deformity.

Aspiration of gastric contents can occur more easily in patients with pharyngeal involvement, such as bulbar palsy complicating motor neurone disease or poliomyelitis, and oesophageal disease as in scleroderma.

Preoperative assessment

The aim of preoperative assessment is to determine the degree of functional derangement of locomotion, pulmonary ventilation and cardiac function, and to predict the likelihood of anaesthetic-induced complications.

A clinical history is essential. As mentioned previously, locomotion may be so restricted that pulmonary and cardiac function is normally unstressed. Details of previous exposure to anaesthesia of the patient or of similarly afflicted relatives can be of great value in helping to plan anaesthesia. Many patients with neuromuscular disease will have recently received drug therapy such as steroids in high doses, and anticholinesterases, which will affect significantly the choice and administration of anaesthetic drugs.
Normal clinical examination should be extended to include some assessment of neurological dysfunction. Myotonia may be detected by observing the rapidity of relaxation after maximal muscle contraction, or by percussing a superficial muscle mass. Obvious muscle-wasting or hypertrophy should be looked for, and its distribution (either proximal or distal) noted. Bulbar involvement may be suspected from speech defects.

Preoperative clinical investigations provide information about the severity of the disease, and a baseline for anaesthetic management.

Blood chemistry should include serum electrolytes and enzymes including creatine phosphokinase, aldolase, lactic dehydrogenase and the transaminases, all of which may be raised in muscle disease. Raised serum enzymes indicate active breakdown of muscle.

Electrocardiography helps to exclude cardiomyopathy.

Chest X-ray is useful to detect cardiac enlargement and pulmonary infiltration and to show pneumatic changes.

Pulmonary function tests such as spirometry and peak expiratory flow rate may help to determine the degree of restrictive respiratory inadequacy. If ventilation is obviously restricted, blood gases should be measured to establish a baseline.

Electromyography and nerve conduction studies can indicate whether the disease is neurological or primarily muscular, and myotonic conditions can be identified specifically.

Muscle biopsy may help to provide a definite diagnosis and prognosis, or may indicate the severity of involvement—particularly in myasthenics, in whom clinical symptoms may be minimal and yet the neuromuscular endplates are severely affected. In patients thought susceptible to malignant hyperpyrexia, in vitro muscle testing can confirm the susceptibility and give some indication of overall and specific drug sensitivity (Ellis et al., 1972).

Summary of neuromuscular diseases in which problems have been reported after specific drugs (for details and references see text).

1. Suxamethonium:
   - myotonic myopathies
   - severe muscle trauma (or crush syndrome) of 1–3 weeks’ duration
   - hyperkalaemia
   - malignant hyperpyrexia susceptibility
denervation
   - hemiplegia
   - multiple sclerosis
tetanus
   - poliomyelitis
   - paroxysmal myoglobinuria
   - von Recklinghausen’s disease (with denervation)

2. Non-depolarizing relaxants:
   - malignant hyperpyrexia susceptibility
   - myasthenia gravis, myasthenic syndrome and neonatal myasthenia
   - restrictive ventilatory failure
   - von Recklinghausen’s disease (with denervation)

3. Thiopentone:
   - porphyria
dystrophia myotonica
   - Huntington’s chorea
   - multiple sclerosis

4. Inhalational anaesthetic vapours:
   - malignant hyperpyrexia susceptibility
dystrophia myotonica
   - cardiomyopathy

5. Anticholinesterases:
   - myotonic myopathies

6. Spinal anaesthesia:
   - multiple sclerosis
dystrophia myotonica

dystrophia myotonica
	enetuses:
   - myotonic myopathies

CONCLUSION

Diseases affecting the neuromuscular system are not uncommon. Some of the complications of anaesthesia in patients with neuromuscular diseases are very dangerous. The anaesthetist who is aware of these pitfalls may either avoid them by careful management, or detect them at a stage when treatment is likely to be effective.

APPENDIX

A classification of neuromuscular disorders, with some examples.

A comprehensive classified list of neuromuscular diseases prepared by the Research Group on Neuromuscular disorders of the World Federation of Neurology is published in the Journal of the Neurological Sciences (1968). The following is an abbreviated version of this classification, which has been only slightly modified and is intended to indicate the great variety of diseases which can affect the neuromuscular system. The examples chosen are encountered frequently, or are of anaesthetic interest or of a classical type. The interested reader is encouraged to read the complete classification, which contains over 400 clinical entities.

I. SPINAL MUSCULAR ATROPHIES AND OTHER DYSFUNCTIONS OF ANTERIOR HORN CELLS

A. Genetically determined
   - infantile and juvenile spinal muscular atrophy
   - peroneal muscular atrophy (Charcot-Marie-Tooth disease)
   - amyotrophy in hereditary-familial ataxias.

B. Congenital (developmental abnormalities)
   - syringomyelia and meningomyelocele with amyotrophy
C. Traumatic
   1. Physical
      spinal cord compression and anterior spinal artery thrombosis
   2. Toxic
      tetanus toxin and strychnine poisoning
D. Infective amyotrophy
   paralytic acute anterior poliomyelitis and herpes zoster
E. Amyotrophy of unknown aetiology
   motor neurone disease
F. Amyotrophy in malignant disease
   carcino-matous motor neurone disease
G. Dysfunction of the motor neurone in metabolic disorders
   tetany and hypoglycaemia
H. Myokymia, cramps and benign fasciculation

II. DISORDERS OF THE MOTOR NERVE ROOTS
A. Congenital
B. Traumatic
   1. Physical and cord compression and ischaemia
   2. Toxic, local anaesthetics, phenol, alcohol
C. Inflammatory—infected or allergic
D. Neoplastic
   neurofibroma, metastases and reticulosis

III. DISORDERS OF PERIPHERAL NERVES
A. Genetically determined
   peroneal muscular atrophy (Charcot-Marie-Tooth disease)
   neurofibromatosis (von Recklinghausen’s disease)
   amyloid neuropathy
   neuropathy in porphyria
B. Traumatic
   1. Physical
      lacerations, birth trauma and entrapment neuropathies (such as the carpal tunnel syndrome)
   2. Toxic
      drugs (barbiturates, chloral, chloroquine, emetine, isoniazid)
      inorganic substances (heavy metals, phosphorus)
      organic substances (carbon tetrachloride, DDT, dinitrophenol)
      bacterial toxins (botulism, diphtheria, etc)
C. Inflammatory
   1. Infective
      leprosy
      malaria
   2. Post-infective
      infectious hepatitis
      infectious mononucleosis
   3. Polyneuropathy of unknown aetiology
      acute febrile polyneuropathy
      Guillain-Barré syndrome
   4. Neuropathy in connective tissue disorders
      disseminated lupus erythematosus
D. Metabolic neuropathy
   1. Nutritional
      beri-beri
      chronic alcoholism
   2. Endocrine disease
      diabetes
      hyperthyroidism and hypothyroidism
   3. Blood dyscrasias
   4. Uraemia
   5. Porphyria
E. Neuropathy of malignant disease
F. Tumours of nerves

IV. DISORDERS OF NEUROMUSCULAR TRANSMISSION
A. Genetically determined
   infantile and juvenile myasthenia
   pseudocholinesterase deficiency
B. Toxic
   botulism
C. Unknown aetiology
   myasthenia gravis
D. Other myasthenic syndromes
   in thyrotoxicosis, malignant disease, lupus erythematosus
E. Cholinergic paralysis
   poisoning or excessive administration of anticholinesterases

V. DISORDERS OF MUSCLE
A. Genetically determined myopathies
   1. The muscular dystrophies
      Duchenne (hypertrophic) type
      facioscapulohumeral limb-girdle
   2. Dystrophic muscular dystrophy
   3. Amyloid neuropathy
   4. Glycogen storage diseases
      glucose-6-phosphatase deficiency (von Gierke)
      amylo-1,4-glucosidase deficiency (Pompe)
   5. Familial periodic paralysis and related syndromes
      hypotonia
      normotonia
      hyperkalaemia
   6. Familial myoglobinuria of unknown causes
B. Trauma to muscle by external agents
   1. Physical (crush syndrome, Volkmann’s contracture)
   2. Toxic
   3. Drugs (steroid myopathy and chloroquine myopathy)
C. Inflammatory
   1. Infections of muscle
      infectious (Bornholm disease)
      bacterial (septic myositis, gas gangrene)
      other invaders (toxoplasmosis, cysticercosis)
   2. Other inflammatory disorders of muscle
      polymyositis (collagen diseases)
   3. Inflammatory disorders of muscle of unknown aetiology
      sarco-myopathy, fibrositis
D. Muscle disorder associated with endocrine or metabolic diseases
   1. Thyrotoxicosis
   2. Myxoedema
   3. ACTH myopathy
   4. Subacute alcoholic myopathy
   5. Hypermetabolic myopathy
E. Myopathy associated with malignant disease
   carcinomatous myopathy
   myasthenic-myopathic syndrome
F. Myopathy associated with myasthenia gravis
G. Other disorders of muscle of unknown aetiology
   1. Acute muscle necrosis
   2. Paroxysmal myoglobinuria
   3. Muscle cachexia (in wasting diseases and in the elderly)
H. Tumours of muscle
REFERENCES


Thiel, R. E. (1967). The myotonic response to suxa-


