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Abstract

Congenital muscular dystrophies are a group of rare neuromuscular disorders with a wide spectrum of clinical phenotypes. Recent advances in understanding the molecular pathogenesis of congenital muscular dystrophy have enabled better diagnosis. However, medical care for patients with congenital muscular dystrophy remains very diverse. Advances in many areas of medical technology have not been adopted in clinical practice. The International Standard of Care Committee for Congenital Muscular Dystrophy was established to identify current care issues, review literature for evidence-based practice, and achieve consensus on care recommendations in 7 areas: diagnosis, neurology, pulmonology, orthopedics/rehabilitation, gastroenterology/nutrition/speech/oral care, cardiology, and palliative care. To achieve consensus on the care recommendations, 2 separate online surveys were conducted to poll opinions from experts in the field and from congenital muscular dystrophy families. The final consensus was achieved in a 3-day workshop conducted in Brussels, Belgium, in November 2009. This consensus statement describes the care recommendations from this committee.

Congenital muscular dystrophies are a group of genetic neuromuscular disorders with muscle weakness presenting at birth or early infancy. The muscle pathology reveals dystrophic or myopathic features. Table 1 lists the names, gene defects, protein products, and clinical features of the common congenital muscular dystrophy types. Advances in molecular genetics and histopathological techniques have enabled the recognition of distinct congenital muscular dystrophy subtypes supported by specific gene identification. Recent breakthroughs in underlying molecular mechanisms drive our understanding of the disease pathogenesis and highlight therapeutic targets. However, despite the rapid progress in basic research, clinical care for patients with congenital muscular dystrophy remains extremely diverse. This can be attributed to 2 main reasons: (1) congenital muscular dystrophies are a group of rare disorders, and (2) the clinical phenotypes are overlapping and can be difficult to distinguish. Clinicians who care for patients with neuromuscular disorders have variable expertise in recognizing and differentiating clinical phenotypes of congenital muscular dystrophy. Also, recent advances in genetic and medical technology have not been widely distributed and accepted in clinical practice. Therefore, there is a great need to establish guidelines for diagnosis and clinical care in congenital muscular dystrophy.

Methods

The International Committee on Standard of Care for Congenital Muscular Dystrophy

In April 2009, a group of physicians met to discuss current clinical care issues for patients with congenital muscular dystrophy and to prioritize the congenital muscular dystrophy care guideline initiative. This core committee later invited a larger group of international experts to form a Standard of Care Committee with 82 members from 7 medical subspecialties. The Standard of Care Committee's mission is to improve the quality of life of people with congenital muscular dystrophy by establishing optimal medical care guidelines. The Standard of Care Committee's goals are to publish 2 consensus statements: an updated Congenital Muscular

Dystrophy Diagnostic Guideline and a Clinical Care Guideline addressing the multiple medical issues in congenital muscular dystrophy. The International Standard of Care Committee for Congenital Muscular Dystrophy includes 7 subspecialty care areas: diagnostics, neurology, pulmonary/ICU care, gastrointestinal/nutrition/speech/oral care, orthopedics/rehabilitation, cardiology, and palliative care. The group met through periodic conference calls and e-mail correspondences to delineate the road maps and timelines to achieve the set goals.

Online Survey of Experts' Opinions on Standard of Care for Congenital Muscular Dystrophy

As a tool to achieve consensus on various care issues, the Standard of Care Committee decided to conduct an online survey to poll the opinions from the committee members. This survey was used to solicit the common practice standard among this group of experts and as the foundation for consensus building. The survey questions were designed by group leaders with the input of all members from each working group. The questions were open-ended and allowed a wide range of responses. A total of 99 questions were posted to address the diagnostic procedure and opinions on acute and maintenance care issues of 6 clinical care areas. All 82 members of the Standard of Care Committee were invited to participate in the survey. The results of the survey were collected and tabulated to allow for a quick overview of each issue within the care areas.

Online Survey of Families' Opinion on Care Issues in Congenital Muscular Dystrophy

An online survey of families and affected individuals with congenital muscular dystrophy, launched by Cure CMD, provided an opportunity for critical input from the congenital muscular dystrophy community. An e-mail campaign solicited 33 responders across the congenital

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Table 1. Common Congenital Muscular Dystrophies

Disease Entity	Protein Product (Gene Symbol)	Clinical Features
Congenital muscular dystrophy with primary laminin 2 (merosin) deficiency (MDC1A)	Laminin α2 (*LAMA2*)	Sitting and standing with support as maximal motor ability; neuropathy; epilepsy in approximately 30%; possible subclinical cardiomyopathy; generally normal mental development
Congenital muscular dystrophy with partial merosin deficiency (MDC1B)	Not known	Rare; variety of severity; delayed onset possible; limb girdle weakness; generalized muscle hypertrophy; early respiratory failure possible
Fukutin-related proteinopathy (MDC1C)	Fukutin-related protein (*FKRP*)	Often reminiscent of MDC1A but severity more variable; generally normal mental development; structural brain involvement and mental retardation possible
LARGE-related congenital muscular dystrophy (MDC1D)	Acetylglucosaminyltransferase-like protein (*LARGE*)	Congenital muscular dystrophy with profound mental retardation can eventually blend with the muscle–eye–brain disease/Walker-Warburg syndrome spectrum
Fukuyama congenital muscular dystrophy	Fukutin (*FCMD*)	Frequent in Japanese population; never walk; mental retardation; epilepsy common—clinical overlap with muscle–eye–brain disease
Muscle–eye–brain disease	Protein-O-linked mannose β1, 2-N-acetylglucosaminyl-tranferase 1 (*POMGnT1*), also caused by FKRP, FCMD	Severe weakness and mental retardation; large head; prominent forehead; flat midface; walking rarely achieved; ocular involvement (eg, severe myopia, retinal hypoplasia); motor deterioration because of spasticity
Walker–Warburg syndrome	O-mannosyltranferase 1 (*POMT1*), also POMT2, FKRP, FCMD	Severe; lethal within first years of life because of severe central nervous system involvement
Ullrich congenital muscular dystrophy and Bethlem myopathy	α$_{1/2}$ and α$_3$ collagen VI (*COL6A1*, *COL6A2*, *COL6A3*)	Distal joint hyperextensibility; proximal contractures; motor abilities variable; precludes independent ambulation in severe Ulrich cases; soft palmar skin
Integrin α7	Integrin α7 (*ITGA7*)	Very rare; delayed motor milestones; walking within 2 to 3 years of life
Rigid spine muscular dystrophy	Selenoprotein N (*SEPN1*)	Delayed walking; predominantly axial weakness with early development of spine rigidity; restrictive respiratory syndrome
Lamin A/C-related congenital muscular dystrophy	Lamin A/C (*LMNA*)	Early motor deterioration; prominent axial weakness with dropped head syndrome; early development of spinal rigidity

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muscular dystrophy subtypes, including 11 collagen VI–related myopathies, 2 dystroglycanopathies, 2 laminopathies, 7 MDC1A, and 11 undiagnosed congenital muscular dystrophies. Survey respondents were asked to identify their congenital muscular dystrophy subtype and list the top 3 care issues. Care issues were described as both "medical" and "social"—revolving around medical care and integration within society. Poor weight gain, managing contractures/scoliosis, managing pulmonary function, and access to experts in the field scored high across all subtypes as areas of ongoing care needs. The diagnostic odyssey, the ongoing emotional toll and responsibilities on families and caregivers, and the lack of reliable information organized into a strategic plan provided upon diagnosis were provided as additional commentary.

Standard of Care Workshop for Congenital Muscular Dystrophies

To achieve final consensus of care standard, the Standard of Care Committee met in Brussels, Belgium, for a 3-day workshop on November 14-16, 2009, supported by TREAT-NMD, Cure CMD, AFM, and Telethon. Leaders of each working group performed a literature review to search for evidence-based practice in each care area and presented the results at the workshop. The workshop participants reviewed the results of the 2 online surveys mentioned above and deliberated within each working group to achieve the consensus recommendations for each care area. These consensus recommendations were presented to the entire workshop participants to allow comments for additions and revisions. The final consensus was composed by all participants of the workshop. Two manuscripts were drafted based on the consensus achieved at this workshop: a Congenital Muscular Dystrophy Diagnostic Guideline and a Consensus Statement for Standard of Clinical Care for Congenital Muscular Dystrophy. We list the Consensus on the Standard of Clinical Care in this article. The diagnostic guideline will be published in a separate article.

Consensus Care Guidelines for Congenital Muscular Dystrophies

This document lists recommendations for 6 clinical care areas for congenital muscular dystrophy: neurology, pulmonary, gastrointestinal/nutritional/and oral care, orthopedics and rehabilitation, cardiology, and palliative care.

Neurological Care

Guidelines for Care of Newly Diagnosed Patients. The initial interview with the family of a newly diagnosed patient should take place as soon as a clinical diagnosis of congenital muscular dystrophy is available, even if a specific genetic diagnosis is not yet known. Although this discussion can take place in the regular clinical examination room, using a separate conference room is often better. The parents should be allowed to bring other family members such as grandparents and mature siblings of the patient. It is important to use lay language and picture illustrations to allow easy understanding. The physician must take into account the educational level and emotional states of the parents. Parents should be encouraged to write questions before and after the meeting because families are often

occupied by the grief of the diagnosis and remember little of what they were told.[1-3] Follow-up meetings for further discussions should be scheduled when needed.

The disclosure interview should address 5 key components: diagnosis, prognosis, recurrence risk if known, treatment plan, and family support and community resources. First, the diagnosis should be explained with regard to the pathogenesis and functional consequences. Second, the prognosis should include the possible progression of the functional disability. All forms of congenital muscular dystrophies have variable life expectancies, and it is often difficult to predict the precise life span for each individual patient.[4-8] However, the clinician should emphasize that prognosis for most forms of congenital muscular dystrophy has improved because of recent advances in medical technology. Third, if a genetic diagnosis is known, the recurrence risk and impact on future family planning should be discussed. Even if the exact genetic defect is not known, recurrence risk can sometimes be discussed using a common genetic model that is often associated with the diagnosis. This discussion can well require a further visit with a genetic counselor. Fourth, the treatment plan should include introducing the multidisciplinary approach, which likely will include pulmonologists, cardiologists, ophthalmologists, physiotherapists, orthopedists, and others if needed. Ideally, the multidisciplinary team should include a palliative care specialist early to improve the quality of life. About 50% of children with congenital muscular dystrophy may not have a specific genetic diagnosis, but the supportive care for them is broadly similar regardless of whether a specific genetic diagnosis is made.[7,8] Fifth, the needs for family support must be specifically addressed. Written information from the pediatric neurologist can be used to obtain specific services. Information for advocacy groups and educational resources including appropriate Internet links, and, if appropriate and available, connections to other families affected by a similar diagnosis should be provided.

Guidelines for Outpatient Neurology/Neuromuscular Clinic Visits. Children with congenital muscular dystrophy should be seen regularly in a pediatric neurology/neuromuscular clinic experienced in congenital muscular dystrophy, ideally with a multidisciplinary team. Infants with congenital muscular dystrophy under 12 months or older children with severe or worsening medical issues (eg, refractory seizures, severe hypotonia, and respiratory and nutrition issues) should be seen at least every 3 to 4 months. Children older than 12 months who are in stable condition can be seen every 4 to 6 months for routine surveillance.

Pediatric neuromuscular specialists should offer anticipatory guidance to promote optimal health maintenance of patients with congenital muscular dystrophy. Anticipatory guidance needs to involve somatic as well as psychosocial aspects. Physical therapy should be focused on the maintenance of function and mobility, prevention or treatment of joint contractures and spine deformities, activities to improve respiratory function like singing or playing wind instruments, adequate seating and wheelchair support, and nutrition and swallowing

surveillance with optimal weight gain. Prevention of severe respiratory infections (vaccines, early antibiotic treatment) is important.

Ideally, in a routine clinic visit the following measurements are taken: blood pressure, heart rate, respiratory rate, weight, height/arm span, and head circumference. Other tests such as electrocardiogram, pulmonary function tests, and pulse oximetry can be obtained as needed. Multisystem surveillance should be obtained in these clinic visits. Concerns of weak cough, shortness of breath, sleep disturbances, morning headaches, and particularly recurrent infections should always be discussed with a pediatric pulmonary expert (see section on pulmonary care). If specific congenital muscular dystrophy type is known to affect the heart (eg, in patients with *LMNA* mutations or α-dystroglycanopathies, children with known cardiac concerns, or those with undefined congenital muscular dystrophy subtype), consensus opinion would advocate for at least 1 pediatric cardiology evaluation (including electrocardiogram and echocardiogram) as a baseline whereas frequency of follow-up surveillance can be deferred to the pediatric cardiologist (see section on cardiological care).[9] Providers should not expect children with congenital muscular dystrophy to track on normal growth curves. Nevertheless, they should follow a near-parallel trajectory. If the child is not gaining weight, is losing weight or gaining excess weight, or has swallowing difficulties, constipation, oral dysmotility, or deformity, he or she should be referred to a dietician, gastroenterologist, and swallowing expert (see section on gastrointestinal, nutritional, and oral care).[10,11] Limb or neck contractures and scoliosis should lead to early referrals to a pediatric orthopedist and/or spine surgeon (see section on orthopedics and rehabilitation care). If there are concerns about mood, behavior, or other psychiatric issues, referrals to psychology/psychiatric colleagues are warranted. If a child has an undefined congenital muscular dystrophy or congenital muscular dystrophy subtype with known eye involvement, it is important to involve an ophthalmologist early to help with diagnosis and track for cataracts, visual impairment, and glaucoma. Children at high risk for developmental delay or learning difficulties should receive early intervention services including speech therapy, physical therapy, and occupational therapy. Psychosocial support must focus on financial aspects (insurance coverage, services availability, and school access) as well as coping strategies to reduce the overall burden of the disease for the family. If possible, pediatric palliative care specialists should be involved early in the management process to address topics such as advance directives (see section on palliative care).

Neurological Care Guidelines for Hospitalized Patients. The common reasons for hospitalization or intensive care unit stays of patients with congenital muscular dystrophy are failure to thrive (poor weight gain or weight loss), respiratory failure, respiratory infections, and seizures. These problems tend to occur in the first 6 months of life in patients with severe α-dystroglycanopathies and merosin deficient congenital muscular dystrophy (MDC1A). Patients with Ullrich congenital muscular dystrophy tend to develop frequent infections with respiratory failure later in childhood or in early adolescence. Admissions for cardiac failure tend to occur in patients with *FKRP*, *Fukutin*, *LMNA*, and *POMT1* mutations during mid- to late adolescence. Seizures occur in Fukuyama congenital muscular dystrophy and α-dystroglycanopathies in infancy and can progress to status epilepticus, whereas seizures in MDC1A in most cases do not occur until late childhood and rarely require hospitalization.[7,8,12] Neuromuscular specialists and pediatric neurologists should play a major role in coordinating medical care during acute or critical illness of patients with congenital muscular dystrophy. Decision on resuscitation status must be addressed by emergency room physicians, intensivists, pulmonologists, and cardiologists, but the pediatric neuromuscular specialist should act as an educator to the inpatient care team regarding the nature of congenital muscular dystrophy. Advice to families should include information about potential risks of elective surgery outside the pediatric specialty hospital. Families should be advised regarding the risk for malignant hyperthermia-like reactions (highest for *SEPN1* patients). The pediatric neuromuscular specialist can work with the anesthesiologist and pulmonologist to facilitate extubation in the recovery room after surgery and to transition to noninvasive ventilation.

Problems Related to Congenital Brain Malformation in Congenital Muscular Dystrophy. Congenital brain malformation in patients with congenital muscular dystrophy can result in multiple problems. These include mental retardation, behavioral and learning problems, autistic features, emotional problems, motor deficits, seizures, and ophthalmological problems.[4,6,8,13-16] Two groups of congenital muscular dystrophy are most often associated with brain abnormalities: the MDC1A and the α-dystroglycanopathies. Within the MDC1A group, the most common finding is white matter abnormality (see Figure 1). In a small percentage of patients, polymicrogyria and focal cortical dysplasia have been described, most often in the occipital lobe. Additional brain stem and cerebellar hypoplasia have been reported in a few cases.[17-23] In the group with α-dystroglycanopathies, there is a spectrum of findings from normal to severe and complex supratentorial and infratentorial abnormalities. These include corpus callosum and septum pellucidum defects, cortical migrational and white matter abnormalities, ventriculomegaly, flat/hypoplastic pons or dysplastic cerebellum, cerebellar cysts, and, rarely, Dandy-Walker malformation as well as encephalocele and Chiari 1 malformation. However, microcephaly sometimes is the only abnormal finding, and there can be mental retardation with normal-appearing brain.[7,8,22,24-27]

Seizures are frequently associated with congenital muscular dystrophies, particularly in those with brain malformations. Seizures are reported in 10% to 30% of MDC1A patients with onset from early infancy to adolescence, even in the absence of a clear cortical malformation. Seizure types vary according to the types of central nervous system abnormalities. They can be absences, atypical absences, or even generalized seizures. Complex focal
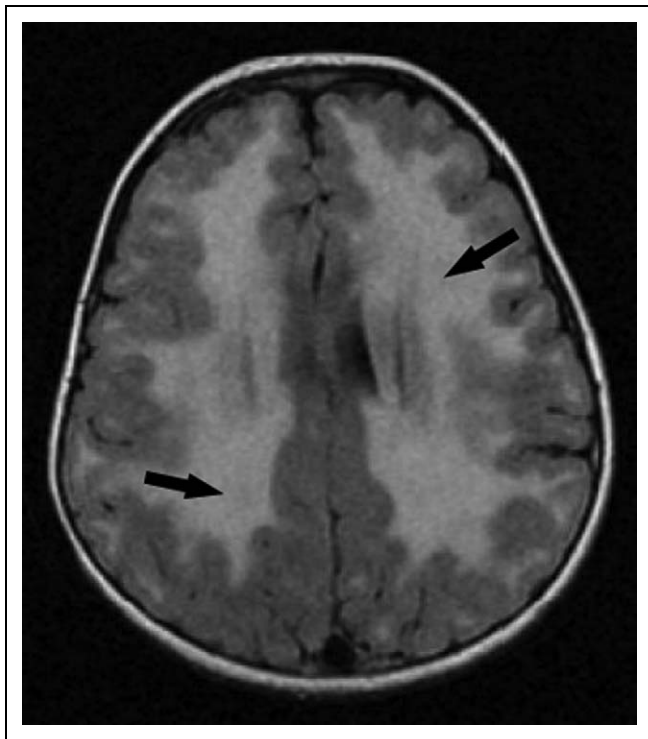
Figure 1. Axial brain magnetic resonance image of a 3-year-old girl with genetically confirmed, merosin-negative congenital muscular dystrophy (MDC1A). Her brain magnetic resonance image showed a "leukoencephalopathy-like" picture with diffuse, symmetric, abnormal signal in the deep and subcortical white matter, centrum semiovale, and corona radiata (see black arrows). The affected white matter is hyperintense on this T2-weighted image.

seizures with or without generalization are more often present in MDC1A patients with polymicrogyria and/or focal cortical dysplasia or in the absence of a clear dysplasia.[4,6,7,18,21] In α-dystroglycanopathies, seizures are reported in Fukuyama congenital muscular dystrophy, muscle–eye–brain disease and Walker-Warburg syndrome.[7,15,28,29] Onset of seizures varies from newborn to adolescence, and seizures are often provoked by febrile illness. The types of seizures are focal and/or multifocal with secondary generalized seizures. Status epilepticus has been reported in 2 patients with muscle–eye–brain disease.[28] Clinical workup should include history of seizures, neurological investigation, baseline, and repeat electroencephalograms as well as cranial magnetic resonance images. Seizures in the MDC1A group are often successfully treated with valproic acid, but other agents have been used successfully. Occasionally seizures can be difficult to control. In α-dystroglycanopathies, anticonvulsant therapy is more often difficult and little has been reported on these. Different anticonvulsants used in this group of patients have included phenobarbital, valproic acid, carbamazepine, phenytoin, levetiracetam, clonazepam, zonisamid, and acetazolamid. Seizures are often difficult to treat in these patients because of their underlying brain malformation.[15,29] There are no data on nonpharmacological management such as ketogenic diet, vagus nerve stimulation, or epilepsy surgery.

Children with mental retardation and learning issues should undergo psychometric testing and be referred to early intervention and augmented/specialized school and communication programs with dedicated evaluations and monitoring. For behavioral, emotional, and autistic problems, referrals to child psychology/psychiatry services are recommended. In α-dystroglycanopathies, detailed eye examination and subsequent follow-ups are indicated. If the child is visually impaired, appropriate education and services should be provided given that visual impairment negatively affects learning and quality of life. As coordinators of care, neurologists should act as advocates when working with day care, school, and other service providers and make sure that they understand the special needs of children with congenital muscular dystrophy.

Pulmonary Care

Respiratory involvement in congenital muscular dystrophy can vary considerably between and within each congenital muscular dystrophy subtype. Symptoms vary in severity according to age of onset and ambulatory status of the patient.[30-37] Our goal is to highlight the respiratory care in congenital muscular dystrophy with specific references to the individual subtypes when information is known and applicable and to provide recommendations for screening and treatment when possible. Although much of the literature reviewed includes patients with congenital muscular dystrophy, many of the studies were done on patients with neuromuscular disease in general and Duchenne muscular dystrophy and spinal muscle atrophy specifically. As a result, some of our recommendations are extrapolated from that data.

Literature Review. All types of congenital muscular dystrophies are predisposed to the development of respiratory failure. Those with SEPN 1–related myopathies, lamin A/C congenital muscular dystrophy, and Ulrich congenital muscular dystrophy often present with spinal rigidity and manifest early diaphragmatic failure even while still ambulatory.[32-34] MDC1A, B, and C have more correlation between motor and respiratory function. Patients with dystroglycanopathies can present with early respiratory failure, usually in proportion with their muscle weakness and developmental delay. Respiratory status can be further complicated by nutritional problems, difficulty swallowing, and scoliosis. Table 2 summarizes the congenital muscular dystrophy phenotypes and their pulmonary symptoms.

Review of the current literature and a survey of physicians involved in the care of patients with congenital muscular dystrophy agree that infants and children under 2 years of age with congenital muscular dystrophy do not always show typical symptoms of respiratory distress because of profound weakness. Tachypnea and retractions can be seen, but respiratory problems cannot be ruled out in their absence. The signs and symptoms of a weak cry, ineffective cough, choking on feedings, or secretions, in addition to weight loss or poor weight gain, have been described in congenital muscular dystrophy; the latter are often referred to as "failure to thrive." These signs and symptoms along with repeated respiratory infections,

Table 2. Congenital Muscular Dystrophy Subtype and Age Range of Onset of Respiratory Involvement[38-40,45,87]

Functional Class	Congenital Muscular Dystrophy Subtype	Age of Onset in Years
Rigid spine/axial weakness, ambulatory	Severe Ulrich congenital muscular dystrophy (collagen VI)	Early and severe, can require ventilatory support at the end of the first decade in most cases
	Selenoprotein N1–related myopathies	Early onset of nocturnal respiratory failure prior to loss of ambulation, ventilated by an average of 10 years old
	Lamin A/C congenital muscular dystrophy	Respiratory symptoms are secondary to restrictive lung disease of variable onset
Hypotonia, nonambulatory	Merosin deficient congenital muscular dystrophy	Correlation between motor and respiratory function, with respiratory failure mean age of 11.6 years old
	Syndromic dystroglycanopathies (Walker-Warburg syndrome, muscle–eye–brain disease, Fukuyama)	Early onset mental retardation, severe progression of muscle weakness and respiratory failure
Muscle weakness, ambulatory	Fukutin-related protein and other dystroglycanopathies	Good correlation between loss of motor and respiratory functions

irritability, or a paradoxical breathing pattern can be the primary presentation of congenital muscular dystrophy or respiratory involvement in a patient already carrying the diagnosis of congenital muscular dystrophy.[38,39] Older children, adolescents, and adults can present with symptoms similar to those of younger children with weight loss, aspiration, and repeated infections. Typical symptoms of respiratory failure such as breathlessness are not always seen because of motor weakness.

Review of literature on pulmonary assessment in congenital muscular dystrophy. Assessment of respiratory status in neuromuscular weakness is done primarily with pulmonary function tests. Spirometry in sitting and supine positions is of particular importance as a difference of more than 20% between the sitting and supine vital capacity (which can be inspiratory vital capacity or forced expiratory vital capacity) is indicative of diaphragmatic weakness and is a predictor of nocturnal hypoventilation.[38,40] A vital capacity of less than 60% predicted is a good predictor of sleep disordered breathing and less than 40% of nocturnal hypoventilation.[41] Maximal inspiratory pressure and maximal expiratory pressure are additional measures of pulmonary function, with normal values ranging from 80 to 120 cm H_2O.[38,39] Values are not available in the congenital muscular dystrophy population, but in Duchenne muscular dystrophy, a value of less than 60 cm H_2O suggests respiratory impairment.[42] A low maximal inspiratory pressure with a normal maximal expiratory pressure is an indicator of diaphragmatic weakness.[39] Peak cough flow, polysomnography, and blood gases are also used to gauge respiratory compromise.[38-40] A peak cough flow can be obtained with a simple peak flowmeter and will help estimate a patient's ability to clear secretions. Peak cough flows of 160 to 270 L/min have been described as acceptable levels to clear the airway; below this point, patients are more susceptible to infection and respiratory failure.[43,44] A mask interface allows children and adults with facial weakness to achieve a reliable value for both peak cough flow and vital capacity. Simply asking a child to cough can also be used to assess cough effectiveness.

Polysomnograms can detect or confirm sleep disordered breathing and should include end-tidal CO_2 monitoring or transcutaneous CO_2 monitoring. Arterial or capillary blood gases assess hypercapnic respiratory failure.[38,39,45]

Review of literature on treatments for the pulmonary symptoms. The primary goals for pulmonary treatments for congenital muscular dystrophy include clearance of secretions and assisted ventilation. No data are available on whether respiratory muscle training is beneficial. Likewise, no systematic comparison on the efficacy of manual percussion and high-frequency chest wall oscillation has been performed in congenital muscular dystrophy, although both forms of secretion mobilization have been integrated into clinical practice. The literature supports the use of assisted coughing techniques, ranging from manual maneuvers such as the chest or abdominal thrust or addition of these maneuvers to chest insufflation. Chest insufflation increases the volume of air in the chest to achieve a more effective cough flow.[43,44] Chest insufflation can be done by breath stacking with glossopharyngeal breathing (frog breathing), an Ambu bag, intermittent positive-pressure breathing, mechanical in/exsufflation (e.g. Cough Assist™), and noninvasive positive-pressure ventilation.[48] Mechanical insufflation–exsufflation and intrapulmonary percussive ventilation have proven useful in inflating the lung with the additional benefit of treating atelectasis and helping clear secretions.[50-52] Mechanical insufflation–exsufflation adds to the insufflation a negative pressure following insufflation to enhance expiratory flow and clearance of secretions.[46,47,49]

Long-term noninvasive positive-pressure ventilation is required when spontaneous respiratory muscle efforts are unable to sustain adequate alveolar ventilation. If reversible deteriorating factors (ie, respiratory infection, heart failure, severe electrolyte disturbance) have been treated successfully, indications for noninvasive positive-pressure ventilation include symptomatic daytime hypercapnea, symptomatic nocturnal hypoventilation, nonsymptomatic nocturnal hypercapnea or hypopneas, failure to thrive, recurrent chest infections

(>3 a year), fatigue, and respiratory muscle weakness as documented by pulmonary function tests.[53-57] There are times when chronic ventilation can require an invasive application via tracheostomy. These include recurrent infection, severe bulbar involvement, inability to tolerate noninvasive positive-pressure ventilation for the amount of time required, ineffective noninvasive positive-pressure ventilation, and severe retention of secretions not controlled by noninvasive measures.[58]

Pulmonary Care Guidelines

Diagnosis of pulmonary problems. A proactive approach should be taken to recognize early symptoms of pulmonary problems prior to the onset of chronic respiratory compromise. This can be facilitated by regularly scheduled physician visits and patient or family awareness of potential signs and symptoms. Early symptoms can be subtle and include disturbed sleep, increased need to turn at night, waking in the morning feeling tired, disturbed mood, and poor concentration during the day. These symptoms are typically related to hypoxemia overnight. Progression to more severe symptoms such as morning headaches, nausea, accessory muscle use, tachypnea, fear of going to sleep, and nightmares tend to be associated with daytime and nighttime hypercapnea. Repeated chest infections, swallowing difficulties, and poor weight gain or weight loss can also be signs of pulmonary impairment. Scoliosis and chest wall deformities can develop secondary to the weak chest muscles and weakened diaphragm, further limiting chest wall excursion and lung expansion.

If the patient is capable of performing spirometry, the forced vital capacity maneuver, a minimum measurement of forced vital capacity and forced expiratory volume in the first second as well as calculation of the ratio of these 2 numbers is needed. This should be done in both sitting and supine positions. For patients incapable of performing standard spirometry secondary to age or developmental delay, a cry vital capacity can be obtained by placing a tightly fitting mask (similar to resuscitation masks) over the nose and mouth with a spirometer in line. The cry will give an approximation of a forced vital capacity. If the patient does not cry, which can occur in children younger than 2 years or a very weak infant, a tidal volume measurement can be obtained.

Diaphragmatic involvement is often asymptomatic and requires a high index of suspicion in patients with congenital muscular dystrophy who have not yet been classified into a subtype and those with rigid spine and/or axial muscle weakness. The congenital muscular dystrophy subtypes in which rigid spine or axial weakness typically occurs include SEPN1-related myopathies, collagen VI–associated myopathies, and lamin A/C. In these subtypes, respiratory failure can occur while patients are still ambulatory. Pulmonary function tests, specifically the comparison of forced vital capacity in sitting and supine positions as well as maximal inspiratory and expiratory pressures, should be used to monitor diaphragm involvement. Regular monitoring of pulmonary function can predict potential changes in a patient's health. Table 3 lists the utility of various pulmonary function tests.

Health maintenance and preventive care. There are several options to maintain respiratory health. Methods that improve cough efficiency and open areas of atelectasis (raised volume therapy or insufflation) should be used in patients with congenital muscular dystrophy. Cough assistance using mechanical insufflation–exsufflation is generally accepted as the care standard for patients with neuromuscular weakness, especially if they have a peak cough flow of less than 270 L/min.[43] The pulmonologist/respiratory therapy team can teach the congenital muscular dystrophy patient other methods of passive insufflation such as breath stacking with an Ambu bag to maintain thoracic compliance and reduce the risk of chronic atelectasis. The use of a daily intrapulmonary percussive ventilation regimen can assist in pulmonary recruitment and clearance of secretions. This helps to decrease atelectasis and maintain vital capacity in the patient with diminished pulmonary function.[55]

Other factors that contribute to pulmonary impairment should be addressed. A decreased forced vital capacity and forced expiratory volume in the first second with a normal ratio of the 2 values are consistent with the restrictive lung disease of neuromuscular disease but require a lung volume measurement by plethysmography or gas dilution to be confirmed. A decrease in both forced expiratory volume in 1 second and the ratio of the expiratory volume in 1 second and the vital capacity is consistent with airway obstruction, assuming a full exhalation. This is not typical of congenital muscular dystrophy but can indicate a diagnosis of asthma and should be treated with bronchodilators and inhaled steroids.

Patients with muscle weakness are prone to gastroesophageal reflux and delayed gastric emptying. Treatment with an H_2-antagonist/proton pump inhibitor with or without a prokinetic agent can be indicated. Speech and swallow evaluation should be considered when there are symptoms of aspiration such as cough, choking, difficulty swallowing, poor feeding, or failure to thrive. Thickened feeds or an alternate method of feeding is needed. Pneumococcal and influenza vaccines are suggested for any patient with congenital muscular dystrophy. It is the recommendation of this committee that palivizumab (Synagis), a humanized monoclonal antibody against respiratory syncytial virus, be given to children under 2 years of age as prophylaxis.

Spinal bracing is required to promote activities of daily living, ensure functional sitting posture, and delay the progression of scoliosis. This allows adequate thoracic growth until optimal timing for spinal surgery. Spirometry both in and out of the brace is recommended to evaluate the impact on respiratory function. Adjustment is needed between the degree of correction and the compression pressure on the thorax to avoid compromise of the respiratory capacity (see Figure 2. for a prototype of Garchois brace). The Garchois brace provides support of the head, back, and abdomen but allows for chest expansion.

Management of acute illness. Respiratory tract infections are the most common cause of hospital admissions and death in

Table 3. Pulmonary Function Tests and Their Indications for Patients With Congenital Muscular Dystrophy

Pulmonary Function Test	Indication
Forced vital capacity sitting and supine, forced expiratory volume in first second, ratio of forced expiratory volume in first second and forced vital capacity, maximal expiratory pressure, maximal inspiratory pressure, peak cough flow	Obtain during routine evaluation, performed at each clinic visit, at least annually
Nocturnal oximetry	Obtain if patient shows increased work of breathing, tachypnea, retractions, restless sleep, decreased functioning during the day, recurrent chest infections, poor weight gain, morning headache, forced vital capacity <60% predicted, or >20% difference between sitting forced vital capacity and supine if sitting forced vital capacity <80%
Nocturnal CO_2 monitoring	Obtain if oximetry has a low baseline of <94% on room air when patient is awake or asleep and/or oximetry drops below 90% on room air for >5 min with a low of at least 85% or >30% of total sleep time spent at <90% saturation
Blood gas	Obtain if there is an acute onset of respiratory distress, if noninvasive CO_2 monitoring is not available, or to correlate with end-tidal CO_2 and transcutaneous measurements obtained
Polysomnography that includes CO_2 monitoring	Obtain to differentiate between central apneas, obstructive sleep apneas, hypopneas, seizures, and gas exchange abnormalities; hypoventilation is present if >25% of the total sleep time is spent with CO_2 >50 torr; obtain if symptoms listed as indication of nocturnal oximetry persist with normal overnight oximetry recording (drop in saturation can trigger an arousal inducing sleep fragmentation); also helpful to titrate best settings for noninvasive ventilation

patients with congenital muscular dystrophy. When a child with congenital muscular dystrophy presents with an acute respiratory infection, the evaluating practitioner must focus on the severity of underlying disease and the symptoms of the acute illness. The parents or primary caregivers are frequently good sources of information about the patient's congenital muscular dystrophy subtype, disease severity, and normal baseline status. Signs of respiratory distress are frequently subtle, such as if the child is paler, is more somnolent, or has a decreased appetite. Paradoxical movement of the thorax or abdomen, tachycardia, and tachypnea can be seen and the cough is weaker. Any of these signs deserve a careful evaluation, but if in addition the oxygen saturation is less than 94% or lower than baseline, the child should be seen immediately.

To evaluate the severity of an acute illness, one begins with a good physical examination and auscultation of the chest. This should include an assessment of cough effectiveness, using either a peak cough flow or asking the patient to demonstrate his or her cough. Pulse oximetry can quickly demonstrate the presence of hypoxemia. If the oxygen saturation is low, supplemental oxygen should be provided. However, CO_2 should be measured because oxygen delivered in isolation can decrease the respiratory drive in certain patients. If there is evidence of acute or chronic CO_2 retention, it is more appropriate to provide positive-pressure ventilation than just oxygen. Chest radiographs will be needed to identify pneumonia and

atelectasis, and comparison with a previous film is needed to accurately evaluate the lung fields in patients with severe scoliosis. A sputum culture should be obtained if the patient has a productive cough. Blood tests including complete blood counts, electrolytes, glucose, blood urea nitrogen and creatinine, and blood culture if febrile will provide additional information.

Treatment of an acute infection requires ongoing monitoring of respiratory status with continuous oximetry and serial blood gases. If frequent blood gases are needed, an arterial line should be replaced early in the course. Respiratory treatments to help mobilize secretions should be intensified. Depending on the patient's home management and availability in the hospital, this can include mechanical insufflation–exsufflation, intrapulmonary percussive ventilation, chest insufflations, and manually assisted cough. Bronchodilators and chest percussion should be used if believed to be appropriate for the infection. If the patient is already on noninvasive ventilation at baseline, he or she will require reevaluation of the ventilator settings and amount of time of use. If the patient is in respiratory failure, noninvasive positive-pressure ventilation should be initiated first, only moving on to invasive ventilation with intubation in cases of failure of noninvasive ventilation, inability to clear secretions with cough assistance and suctioning, or the loss of ability to protect the airway with high risk of aspiration.[59] Forms of airway clearance remain critical to recovery and
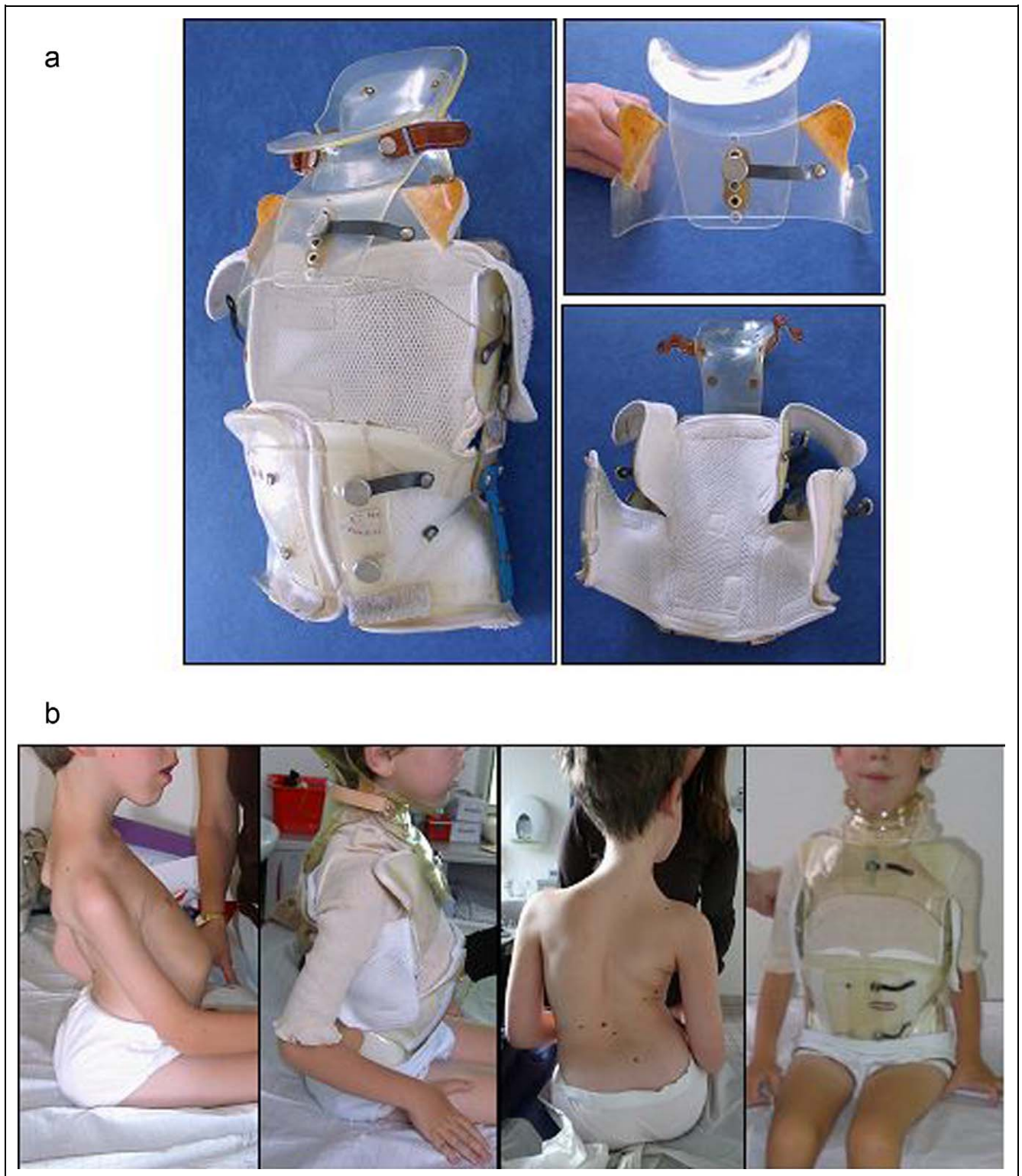
Figure 2. A prototype of the Garchois brace, a trunk orthosis created to prevent or treat spinal deformities. It allows comfortable and stable sitting position and does not impair respiratory function.[73] A mold is made with the patient in lying position while cervical and pelvic tractions are opposed to reduce the spinal deformity (corrective molding). (a) It is made of plexidur, a rigid but light and heat-deformable material, and is constituted by several pieces attached. A back piece allows elongation of the trunk length in order to follow spinal growth. The brace does not interfere with respiratory function because of the absence of thoracic compression. Trunk weight is supported on the hips, and prevention of spinal collapse is obtained by prehumeral supports. A neck piece allows head support or offers a slight cervical traction to prevent spinal collapse. (b) A patient with merosin-deficient congenital muscular dystrophy (MDC1A) showing partial correction of dorsal and lumbar lordosis (lateral view) and of the scoliosis (frontal view).

should continue to be used even if the patient is on noninvasive or invasive assisted ventilation.

Presurgical and postsurgical management. An intensive, proactive, multidisciplinary approach should be instituted prior to any surgical procedure or procedures requiring anesthesia, sedation, or a prolonged period of lying supine. The emphasis should be on the anticipation of respiratory problems and nutritional health. Common surgical procedures in patients with congenital muscular dystrophy include scoliosis repair, extremity contracture releases, and dental care. Patients should be encouraged to inform their primary neuromuscular physician and their pulmonologist of any proposed intervention to ensure there is communication between disciplines. Preoperative assessment should include an evaluation of cough and overnight oximetry in at risk patients. If not already using a method to assist coughing, the patient should be trained in such a method prior to surgery, with an emphasis on learning how to use the mechanical insufflator–exsufflator. If there is a chance that the patient will need assisted ventilation after surgery, noninvasive positive-pressure ventilation should be introduced preoperatively. Early extubation to noninvasive ventilation should be considered following surgery with aggressive use of the mechanical insufflator–exsufflator to help prevent atelectasis and pneumonia. Patients and families should be taught how to use all equipment prior to surgery and should have it available postoperatively. Nutrition should also be addressed before surgery. If the patient is in poor nutritional balance, wound healing can be delayed and the patient can be too weak to adequately clear secretions or maintain ventilation. Nutritional supplementation in patients in borderline respiratory failure should be approached with the awareness that carbohydrates when metabolized into carbon dioxide will be an additional burden to ventilation.

Noninvasive positive-pressure ventilation. Long-term noninvasive positive-pressure ventilation has become a widely used treatment for neuromuscular patients with advanced respiratory impairment, mostly because of the availability of comfortable nasal interfaces and increased practitioner experience. Use of noninvasive positive-pressure ventilation has been shown to improve gas exchange, improve survival, decrease infections, decrease length of hospital stays, and decrease hospitalizations in patients with neuromuscular disease.[60] Clearly advantageous, noninvasive ventilation has assumed a central role in the management of patients with congenital muscular dystrophy both in acute care situations and for home maintenance.[45,54,55] Noninvasive positive-pressure ventilation is initiated when there is evidence of alveolar hypoventilation with nighttime or diurnal hypercapnea.[61] There is a role for chronic noninvasive positive-pressure ventilation in congenital muscular dystrophy in the setting of recurrent infection or poor weight gain even in the absence of chronic hypoventilation. It also has utilization as a chronic treatment after a patient has been intubated secondary to acute respiratory failure. Noninvasive positive-pressure ventilation has also been used as a form of insufflation in the absence of chronic hypoventilation and after a rapid decline in pulmonary function tests. The institution of noninvasive ventilation needs to be followed by overnight monitoring of oxygenation and carbon dioxide levels, during which period the appropriateness of mask fit, the need for a chin strap, and the response in ventilation can be assessed. A possible complication of long-term noninvasive positive-pressure ventilation with a facial or nasal mask interface, when initiated in the young child, is distortion of midface structure and hypoplasia. The combination of midface hypoplasia due to long-term face mask use and jaw contractures, common to certain congenital muscular dystrophy subtypes, can progressively impede feeding and affect airway management in the acute setting. Using individually fitted masks or alternating between nasal pillows, nasal masks, and full face masks can help prevent midface hypoplasia. Sip ventilation with a mouth piece can also be used in patients who can make a seal with their lips.

Invasive positive-pressure ventilation. There are times when long-term mechanical ventilation requires an invasive application via tracheostomy. This can occur in patients with severe bulbar involvement leading to chronic aspiration and repeated pneumonia or with ineffective clearing of tracheobronchial secretions despite the use of noninvasive manual or mechanical expiratory aids.[46] A tracheostomy can also be used in patients who cannot tolerate noninvasive ventilation or cannot tolerate it for the number of hours per day that ventilatory support is needed.[53] Sometimes, a tracheostomy can be performed because of patient or caregiver preference or because a facial structural abnormality makes masks difficult to fit properly.

Conclusion. The key to care of the respiratory problems in congenital muscular dystrophy is a proactive, preventive approach. Careful monitoring of symptoms, regular assessment of pulmonary function, appropriate perisurgical management, and aggressive treatment of respiratory infections are the standard of care. More research is needed regarding recognition and evaluation of early respiratory symptoms of infants and the use of insufflation techniques in an attempt to preserve pulmonary function and decrease the risk of respiratory infections.

Gastrointestinal, Nutritional, and Oral Care

Feeding and nutrition problems are frequently encountered in patients with congenital muscular dystrophy and should be identified and addressed by a multidisciplinary team. Care and management recommendations are based on scarce literature and extrapolation of data from other neuromuscular disorders and expert opinion.

Literature Review. Literature on feeding, swallowing, and oral features specific to congenital muscular dystrophy is limited to a few observational group studies in MDCIA congenital muscular dystrophy,[11] Ulrich congenital muscular dystrophy,[33] and rigid spine syndrome.[61] Documentation of treatment and

intervention for swallowing and feeding problems are limited; a Cochrane review found only anecdotal evidence from expert clinical opinion for treatments advocating dietary manipulation, safe swallowing techniques, enteral feeding, and surgical interventions (cricopharyngeal myotomy, botulinum toxin, and dilatation). No literature on the presentation or management of speech difficulties was identified in this population.

Results of Online Surveys on Feeding and Nutrition Care Issue. Four areas of concern were identified from the professional and parent surveys conducted by the current committee: nutrition and growth, feeding, gastrointestinal motility (gastroesophageal reflux, dysmotility, and constipation), and oral care. The majority of experts relied on regular physical examination, history taking, and serial anthropometric recording of weight, height, and growth charts to detect and monitor gastrointestinal and nutritional issues. Assessments by a speech–language therapist, an occupational therapist, a dietician, and/or a gastroenterologist were recommended. Dietary recall and food diary were advocated. Therapeutic interventions advocated were good hydration, adequate food, and calorie, vitamin and mineral supplementation. Gastrostomy tube feeding was recommended with or without Nissen fundoplication, taking into account its pros and cons. Laxatives, prokinetics, antacids, proton pump inhibitors, antiemetics, and probiotics were medications to consider. A fiber-rich diet and frequent mobilization of the body were mentioned as remedies for constipation.

There is an emphasis on multidisciplinary intervention. Issues of feeding and nutrition are multifactorial and closely related to other areas of care: for example, nocturnal hypoventilation can affect appetite and growth, and poor respiratory function can result in easy fatigue and difficulty in swallowing.

Recommendations for Gastrointestinal, Nutritional, and Oral Care

Clinical assessment of feeding, nutrition, and growth. Identification and assessment of feeding difficulties are essential for optimal care of patients with congenital muscular dystrophy. One of the problems in monitoring nutrition and growth is the absence of appropriate growth charts and data on energy and nutritional requirements in this population. The most encountered problem is undernutrition and poor weight gain. Overweight also has to be considered, particularly in the adult population because of the limited mobility of these patients. Growth should be screened by regular weight measurements, complemented by height measurements or a surrogate height measurement (arm span or ulnar length).

Patients with congenital muscular dystrophy often have a growth curve below what is expected for age. This is acceptable if the child is in good health and has no signs of fatigue, recurrent infections, or cardiac and respiratory dysfunction. This underscores the need for regular assessment including detailed history taking for feeding issues and full physical examination. Despite the lack of appropriate growth charts, stagnated growth is a concern in a growing child, necessitating repeated measurements that can require nutritional interventions. When nutritional problems are identified, they warrant

further assessment by specialists experienced in feeding and swallowing evaluation.

Feeding and swallowing difficulties have been identified as significant problems for some patients with congenital muscular dystrophy. Children with dystroglycanopathies and neurological impairments often have problems with oral coordination, resulting in drooling, difficulties with chewing and swallowing, and risk of aspiration. Similar problems can be observed in children with MDC1A and Ulrich congenital muscular dystrophy. The need for texture modification and prolonged mealtimes can result in inadequate calorie intake and poor growth. Videofluoroscopy can demonstrate difficulties in the oral phase, delay in pharyngeal swallow, and increased risks in aspiration.[11] Neck flexor weakness is a specific problem in children with Ulrich and rigid spine congenital muscular dystrophy, leading to poor head and neck positioning for safe and efficient swallowing. Sometimes there is also extensor weakness and retrocollis in lamin A/C–related congenital muscular dystrophy.[33,61] Other associated factors such as scoliosis, difficulties with positioning and seating for feeding, weak cough, respiratory fatigue, nocturnal hypoventilation, poor appetite, and gastrointestinal issues such as gastroesophageal reflux and dysmotility need to be considered in the assessment of the child presenting with feeding and swallowing difficulties.

Feeding and swallowing problems should be regularly screened during routine clinic visits. Key screening issues are these:

- Length of mealtimes: more than 30 minutes per meal is considered to be prolonged.
- Frequency of meals: increased meal frequency may be needed and clinicians need to ensure that families can carry this out without difficulties.
- Frequency of pulmonary infections.
- Difficulties chewing; choking and coughing.
- Food texture modification.
- Family stress or enjoyment of mealtimes for the child and parents.
- The ability to feed independently.
- Position for feeding.

Identification of difficulties in the above areas warrants further assessment by a specialist qualified in feeding and swallowing evaluation. Assessment should include an orofacial examination, observation and evaluation of feeding and swallowing skills, and observation and evaluation of seating and positioning. The use of a video-fluoroscopic swallow assessment to objectively assess the swallow should be done by speech and language specialists. Endoscopic evaluation of swallow is an underused assessment in pediatrics, specifically in this population.

Treatment and management of feeding problems. Treatment and management of feeding-related problems such as swallowing difficulties and or problems with nutrition or growth should focus on safe and adequate intake. Providing advice about

healthy eating habits immediately after diagnosis is a proactive way to prevent undernutrition or overweight as well as to maintain optimal bone health. Management strategies are based on multidisciplinary assessment and can include adaptations to positioning and seating, supports for self-feeding including adaptation of utensils and aids to feeding, safe swallowing techniques, and texture modification. Progress should be regularly evaluated. There may be some benefit of sensory intervention and oral tasks aimed at optimizing range of movements, particularly maintenance of jaw opening and range of head and neck movement.

If symptomatic management is insufficient, the use of tube feeding has to be considered. Nasogastric tube feeding should be reserved for short-term use such as before and after surgery or during acute illness. Gastrostomy or jejunostomy is the treatment of choice for long-term enteral feeding. Tube feeding is considered beneficial for nutrition and general well-being of both child and family by reducing the stress of achieving adequate intake in a child with feeding difficulties. However, care providers should be aware of the burden of continuous and/or night feedings and be sensitive to parents' fears of altering their roles in feeding. The frequency and volumes of tube feedings should be adapted to reduce the risk of gastroesophageal reflux and dysmotility and to meet fluid and nutrient requirements.

There is no consensus about the use of Nissen fundoplication. Some centers advocate simultaneous surgical procedure including both gastrostomy and Nissen fundoplication, whereas others advocate simple percutaneous gastrostomy or jejunostomy without further procedures. To choose the safest procedure for any of these surgeries, a pediatric anesthesiologist should be consulted, taking into account underlying respiratory problems, risk of aspiration, and advice of the surgeon.

Gastrointestinal motility. Gastroesophageal reflux and gastrointestinal dysmotility, such as delayed gastric emptying and constipation, are frequently encountered problems. Frequent occurrence of symptoms suggesting gastroesophageal reflux, such as chest/upper abdominal pain, vomiting, aspiration, and recurrent respiratory infections, warrant further assessment and management. Medical management of gastroesophageal reflux includes the use of proton pump inhibitors and antacid treatment. Constipation is of multifactorial origin, and attention should be paid to adequate food texture, fluid intake, position and mobilization, and the use of a laxative if needed to ensure regular bowel movement and prevent the development of megacolon. Use of paraffin oils is to be avoided because of the risk of reflux and aspiration in this population.

Perioperative care and management during acute illness. The committee agreed about the need to optimize nutrition and hydration prior to and after surgery. The ideal preoperative weight and nutritional status are unknown, but it is preferable for patients to enter surgery well nourished. It may be necessary to consider short-term preoperative nasogastric tube feeding or gastrostomy, and those children should return from surgery

with a plan and mechanism to ensure good postoperative nutrition, as there can be increased nutritional requirements for recovery. The need for an anticipatory management plan for bowel movement is important as this can cause significant postoperative problems. Oral hygiene should be optimized and the mouth free of infection before surgery. Identifying difficulty in jaw opening reduces the potential for problems with oral intubation. During acute illness, there may be a need to use short-term nasogastric tube feeding to prevent weight loss.

Speech. Children with congenital muscular dystrophy may present with articulatory speech sound errors and substitutions. The anterior open bite, malocclusion, and facial weakness lead to difficulties with lip closure for production of some sounds, and as a result compensatory articulatory patterns can develop. These children present with a further dysarthric pattern of speech production due to weak breath support for phonation that can affect pitch and loudness. Palatal incompetence can lead to nasal resonance of speech.

Oral motor therapy and exercises can help normalize oral sensory function and prevent the development of oral aversion that can result in poor tolerance of oral feeding and difficulties accessing the mouth for optimal oral hygiene. There may also be benefit in maintaining the optimal range of movement particularly of jaw opening. There is no evidence that isolated oral motor exercise will increase the strength of the oral musculature or improve speech. Any proposed interventions should follow an objective measurement and should be for a prescribed period and with measurable outcomes. Further research in the field is required to prove the effectiveness of such interventions and not increase the burden of care without known outcome. Speech therapy intervention may need to focus on compensatory communication strategies.

Oral health issues and dental care recommendations. There is scant scientific literature on oral health issues in congenital muscular dystrophy.[63] The mouth is the entry to the gastrointestinal tract, and weakness of oral muscles, oral hygiene, dental disease, malocclusion, and reduced mouth opening can all have an effect on nutrition and speech. Continuous gastroesophageal reflux can cause serious erosion of dental enamel and pain. Weakness in the masticatory muscles can affect chewing ability. Oral bacteria from dental caries or other infections can contribute to development of pneumonia. Mouth breathing can lead to dry mouth and increased risk of oral infection. Malocclusion with crowding of teeth can make tooth cleaning difficult. Malocclusion can increase over time because of imbalance in oral muscles.[64] Gingival hyperplasia can occur because of prolonged "nothing by mouth" status.

Reduced ability to swallow and cough must be taken into account when seating the patient in the dental chair. Risks concerning cardiac involvement and reduced lung capacity will also influence treatment planning.

Children with congenital muscular dystrophy should be referred to a pediatric dentist at an early age: before 2 years of age or at diagnosis. Frequent follow-up visits are

recommended (at least every 6 months). Molars with deep fissures should be sealed. Professional tooth cleaning should be carried out at each visit, and parents and caregivers should be advised on home care with adequate tooth cleaning, use of fluorides, and antibacterial mouth wash. Special equipment can help the older child and adult to manage tooth cleaning independently. It is recommended that an orthodontist assess malocclusion around the age of 6 years. The orthodontist must be aware of weak and imbalanced activity in oral muscles and take that into consideration in treatment planning.[65] Adults with congenital muscular dystrophy should continue to visit a dentist/dental hygienist regularly for check-up and professional tooth cleaning. In some cases, home visits by a dental hygienist are recommended.

Topics for future research. As for other rare disorders, we need more data on natural history, anthropometrics, and body composition. There are still unresolved questions about optimal timing of gastrostomy, the indication for simultaneous Nissen fundoplication, and optimal nutrition and supplementation in this patient population. The effectiveness and timing of orthodontics and effects of oral muscle training should be assessed.

Orthopedics and Rehabilitation Care

One of the most common problems in all forms of congenital muscular dystrophy is orthopedic deformity of the limb, joint, and spine. These deformities include joint and neck contractures, scoliosis, foot deformity, and hip dislocation or subluxation. Upper extremity functional limitation and reduced mobility can result from both the orthopedic deformity and underlying weakness. Musculoskeletal pain can contribute to functional limitation and impair quality of life.

The severity, type, and localization of orthopedic complications can be useful in diagnosing the type of congenital muscular dystrophy, and diagnosis of a specific type of congenital muscular dystrophy can help inform and guide the orthopedic management: COL6/Ullrich-Bethlem and LAMA2/merosin–deficient patients are more prone to diffuse contractures, patients with SEPN1 have more axial involvement, patients with COL6 disorders/Ulrich typically have kyphosis or kyphoscoliosis, and patients with SEPN1, LMNA, or LAMA2 mutations often have thoracic–cervical lordosis. This is due to particular neck weakness with head lag (LMNA, SEPN1) or late stiff hyperextension of the cervical spine.

Children are growing individuals, and orthopedic management of problems will depend on the dynamic changes of growth in the first years of life. Optimizing the orthopedic care of children with congenital muscular dystrophy is critical to their future level of function. Orthopedic treatment and rehabilitation intervention must be seen as both short-term and long-term issues and viewed as an investment for the future. Since these orthopedic problems can present at birth or develop rapidly early in life, invasive or surgical treatments may not be the satisfactory initial solution, and early conservative/

nonoperative intervention aimed at prevention is preferred as a first approach.

Quality of life can be influenced by the orthopedic state of the patient, depending on how the individual is able to function in social and academic settings. Limitations in these activities can depend on the orthopedic complications that are present or develop over time.

Each child should have regular access to a multidisciplinary team specializing in neuromuscular diseases. Yearly evaluation is a minimal recommendation, and the frequency of the visit will depend on the natural history of the specific congenital muscular dystrophy and the health status of each individual. More frequent evaluation is necessary in younger children; in those with severe hypotonia, respiratory insufficiency, or an unstable or rapidly deteriorating course; and in those with poor response or intolerance to treatment. The ultimate goals of orthopedic and rehabilitation management are to preserve function and independence, promote safety, relieve pain, and maximize quality of life. Orthopedic and pulmonary managements should be closely coordinated since some orthopedic interventions can interfere with pulmonary function. Local services and parents should be educated on how to monitor the intervention and to seek expert consultation should the response or tolerance to the treatment intervention not be as expected.

Literature Review. Review of the literature revealed limited data or evidence specific to congenital muscular dystrophy in regard to orthopedic or rehabilitation management. Literature that did cite congenital muscular dystrophy often included individuals with congenital muscular dystrophy in combination with other neuromuscular disorders[66,67] or diagnoses that incurred problems with posture,[68,69] deformity, and/or pain.[70,71] An article specific to congenital muscular dystrophy,[72] published in 1979, provided important and still relevant information in regard to orthopedic problems that present at birth including arthrogryposis, hip dislocation, scoliosis, and talipes equinovarus. The article reported the chronic problems in congenital muscular dystrophy including weakness, presentation and progression of contractures in upper and lower extremities, the influence of lower extremity contractures on obtaining and maintaining ambulation, and information as to the presence and progression of scoliosis.

Online Health Professional and Family Survey Results. The online survey of expert health professionals regarding orthopedics and rehabilitation included questions regarding assessment, treatment, and management of joint contractures and questions about spinal deformity and surgical intervention.

Assessment. The survey revealed that most medical centers providing multidisciplinary neuromuscular care include members in physical therapy, orthotics, occupational therapy, physical medicine, orthopedics, and neurology. The main orthopedic complications observed in congenital muscular dystrophy by the survey respondents included joint contractures, scoliosis, foot and spine deformities, rigid spine, hip dislocation, and joint

hypermobility. When respondents were asked how these complications were assessed during follow-up, responses included goniometry, spinal assessment, observation, physical examination, radiograph, functional scales, dual energy radiographic absorptiometry, manual muscle testing, range of motion assessment, and handheld dynamometry. Important nonorthopedic issues that must be taken into account in the management of orthopedic issues during follow-up included nutrition, cardiac status, respiratory problems, bone density, puberty, state of growth, urological problems, pain, social situation, weight gain, classroom accessibility, and home environment. Nonorthopedic issues that were expressed as needing to be addressed before and immediately after surgical intervention included nutrition, cardiac status, pulmonary status, adequate treatment of pain, bone density, behavior issues, and family compliance. Symptoms and signs that would alert the clinician to these issues included decreases in functional vital capacity, reduced forced expiratory volume in 1 second, reduced maximal inspiratory and expiratory pressure, dyspnea, sleep disturbance, lack of concentration, loss of appetite, weight loss, fatigue, pathologic fractures, and failure to thrive.

Treatment. Reasons that prompted a referral to physical and/or occupational therapy included the diagnosis of congenital muscular dystrophy contractures, loss of motor function, decreased mobility, altered gait, abnormal positioning, muscle weakness, pain, scoliosis, problems with transfers, joint deformity, and loss of activities of daily living. Equipment recommended for assistance in standing, ambulation, and/or other forms of mobility included canes, walking frames, standing frames, swivel walkers, knee–ankle–foot orthoses, ankle–foot orthoses, reciprocating gait orthoses, scooters, and wheelchairs. Responses to questions about prevention and management of joint contractures were mixed, with some respondents recommending physiotherapy for joint stretching and splinting and tendon releases if conservative therapy failed and others noting they did no splinting or surgical release as there was no evidence to support these measures. Suggested splinting included serial casting and static, static progressive, and nocturnal splinting.

Management of spinal deformities. Respondents reported that management of spinal deformity in congenital muscular dystrophy was dependent on type of congenital muscular dystrophy, age of the individual, and severity of scoliosis. Conservative management included standing frames, positioning, and bracing. There were varying opinions on whether the conservative approach was preventive and comments that studies were not available to answer the question.

Surgical treatments. Respondents reported the importance of growing rods but emphasized that the choice of the instrumentation depends on the age of the patient, the patient's ability to grow, and the severity of the scoliosis. In younger patients, the Vertical Expandable Prosthetic Titanium Rib, an expandable prosthesis that can be extended as the child grows, was recommended for growing patients, but recurrent surgeries are necessary to lengthen the rods, and the device can limit the costal

mobility and therefore affect pulmonary capacity. Some respondents observed variable outcome of this procedure in their institutions. The survey results emphasized the management of respiratory insufficiency both preoperatively and postoperatively and the importance of having a pulmonary team with experience in congenital muscular dystrophy. Suggested contraindications to spinal surgery included family decision, very poor or deteriorating cardiac status and/or respiratory status, very young age, potential loss of function after spinal fixation, and severe scoliosis. Severe respiratory insufficiency may not be a contraindication in certain highly specialized centers, provided invasive ventilation is accepted by the patient and families. Secondary orthopedic complications after spinal surgery included neck hyperextension, hip extension contractures, persistent pelvic obliquity, and pressure sores. Recommendations to manage or prevent these secondary complications included choosing an experienced surgeon and rehabilitation team, encouraging mobility, having a rehabilitation team in place both preoperatively and postoperatively with regular follow-up, and providing appropriate equipment, positioning, and seating.

The family survey revealed that priorities in regard to orthopedics and rehabilitation included contractures, weakness, fatigue/stamina, posture, spinal deformity, activities of daily living, gait, mobility, and safety. Families were concerned about access to therapy services, including appropriate equipment and information, and about whether orthopedics/rehabilitation professionals were educated about the congenital muscular dystrophy diagnosis and its implications. Major concerns were noted regarding social interactions, the school environment, and the transition to independent living and adulthood.

Recommendations

Conservative management. From the day of symptom onset, preventive therapy is an essential part of daily management. Contractures, once developed, are not easily improved in many forms of congenital muscular dystrophy. Regular stretching should include the joints of the limbs, iliotibial bands, neck, spine, and jaw, using active and passive techniques during the day and passive positioning at night. Specific techniques include splinting, stretching, standing programs, and serial casting. Maintaining good posture and spinal alignment should be accomplished through training correct seating, standing, and bracing. Environmental modifications may be needed. Specific consideration should be given to head support, trunk support, and pelvic alignment without compromising respiratory function and with consideration of comfort and function. In patients with respiratory insufficiency, specific braces respectful of respiratory function[73] and not compressing the thorax are required. Garchois plexidur is a good example (see Figure 2).[74] When the brace is not sufficient to halt the progression of scoliosis splinting, casting and halo traction can be used to reduce deformity but require close respiratory monitoring. When orthoses and splinting are the treatment considerations, collaborating with an orthotist who is experienced in treating individuals with neuromuscular disorders is essential. Goals for the use of orthotics and splinting include spinal support and posture correction; contracture

management; facilitation of standing, walking, sitting, and upper limb function; and assistance in pain management.

Mobility, function, and activities of daily living are important considerations. The rehabilitation specialist's role is to ensure that the child has the highest level of comfort, safety, and independent mobility and function. This can include appropriate wheelchair prescription and customization according to the child's needs and level of disability. Early and adequate posturing of feet and neck is of supreme importance for prevention of foot deformities and hyperextension of the neck often seen in patients with LMNA, LMNA2, and COL6 mutations. Activities of daily living and function should be reviewed regularly to ensure the best possible quality of life for the child and family. This can include transfer aids and adaptive equipment to ensure the highest degree of independence and safety. Standing and ambulation should be encouraged if achievable based on assessment of each individual child. Goals of weight bearing include achieving the upright posture to aid in the management of contractures, to promote joint and bone development, and ultimately to promote standing and walking. These goals can be promoted with the use of bracing and/or other specific aids and interventions that assist in the stability in standing.

Recent publications emphasized the importance of rehabilitation in the management of pain.[5,6] Pain relief can be achieved through a variety of modalities: exercise with hydrotherapy to preserve range of motion and prevent edema and swelling of extremities, as well as appropriate positioning for sleeping, sitting, and standing. Correct fit and use of orthoses are essential, along with compliance and regular review of the device. Participation in sports, community, and peer-related activities should be encouraged to help patients maintain general health and well-being. No data are available to show that exercise can improve or maintain function or that it worsens the disease. When conservative management fails, surgical management may be necessary.

Surgical management of lower extremities. Surgery for lower extremity deformities has to be considered very carefully after thorough discussion of the pros and cons of the considered procedure. Any of these procedures has to be considered in terms of the global functional status of the patient. Good preoperative counseling is mandatory. The indications for surgery are to improve or maintain function, reduce pain due to severe contractures, improve fitting of supporting orthoses (eg, hip–knee–ankle–foot orthoses) to maintain standing posture, and improve the sitting position in case of severe hip flexion contracture. The risks include recurrence of the deformity and pain due to postoperative fibrosis, with worsening of the functional status, and residual pain for extremity and spine surgery.

Surgical management of hips. The indications for surgery in patients with subluxation or dislocation of the hip depend on the global functional status. In the absence of objective data, treatment decisions are often based on common strategies used for hip dysplasia associated with other neuromuscular diagnoses. In addition to depending on ambulatory status, treatment decisions are influenced by the age of the patient and the severity and chronicity of the hip dysplasia. For nonambulators, the indications include reducing intractable pain due to hip dislocation and improving hip abduction to facilitate management and hygiene. For walkers, unilateral hip instability might be considered for surgical stabilization. The preoperative functional status has to be carefully analyzed. Ideally, this surgery is performed early before complete dislocation occurs. Early mobilization is recommended to avoid postoperative stiffness.

Surgical management of knees. Indications for surgery are rare. One clinical situation leading to surgery is the inability to sit due to severe contractures (greater than 90 degrees).

Surgical management of ankles. Tendon Achilles lengthening (isolated or combined with more extensive releases) can be considered for release of deformity and improvement in functions such as walking and maintaining good posture. This procedure also can relieve pain to allow shoe wearing. However, careful evaluation of surgical risks is recommended, in particular the possibility of impairing walking ability, if pelvic girdle weakness is significant.

Surgical management of upper limbs. Indications for surgery are extremely rare, and surgery should be considered only in some cases. Surgery for upper limbs is controversial and has uncertain outcomes.

Surgical management of spinal deformities. Spinal deformities are one of the most important areas of orthopedic care. Some patients (eg, those with moderate forms of "rigid spine syndrome") might not need spinal fusion and will remain functional with a moderate trunk imbalance. Other patients can develop severe spinal deformities with life-threatening consequences due to respiratory insufficiency. Early evaluation and careful monitoring of the spinal deformity are essential. Long-term follow-up after surgery is recommended. Decompensation of the postoperative status is possible with progressive cervical hyperextension and pelvic obliquity leading to revision surgery. For those with early onset (infantile congenital muscular dystrophy) and rapid progression, conservative management should be considered initially. Effective bracing is given with consideration of respiratory problems (and gastrostomy), and a soft spinal orthosis is recommended most frequently. Surgery should be performed only when conservative management cannot be applied or has failed. Nonfusion techniques such as growing rods or the Vertical Expandable Prosthetic Titanium Rib can be used to preserve trunkal growth and respiratory development when nonoperative measures have failed or are contraindicated. However, multiple surgical interventions are required, and these measures may require conversion to a definitive spinal fusion when the pulmonary system has matured and trunk height has been maximized.

Surgical management of progressive spinal deformity in the older child. Spinal surgery has been shown to improve quality of life.

The main goals are to improve seating and stabilization and to enhance pulmonary function. Significant risks are involved, and a multidisciplinary preoperative evaluation is important to reduce these risks. Significant risks include excessive bleeding and infection, and intraoperative neuromonitoring is recommended. Besides the posterior procedure, anterior vertebral fusion may be required in severe scoliotic curves.

Regarding the length of the spinal fusion, we have to distinguish walking from nonwalking patients. In ambulatory patients, the fusion length should spare the lumbosacral junction if feasible. The risk of losing the ability to walk after surgery exists but is not commonly observed. However, because of progressive loss of function over time, there is a significant risk of developing secondary pelvic obliquity requiring surgical revision. In nonambulatory patients, the fusion should be extensive and should include the upper thoracic spine and the pelvis. One of the significant problems in these patients is a progressive fixed cervical hyperextension, which can significantly impair function. In those cases, spinal fusion up to the upper cervical spine (C3) should be considered. Perioperative considerations by a specialist team including pulmonology, anesthesiology, dietetics, and cardiology will facilitate the above.

Postsurgery management. Postoperative respiratory management by an experienced team including physical therapists is essential to improve outcome. Nutritional aspects must be considered to ensure that maintenance of weight is achieved. Considerations for postoperative care include these

- Intensive pulmonary treatment in the following 6 months (insufflation techniques, prolongation of mechanical ventilation) may be needed.
- Self-feeding can be more difficult initially.
- Wheelchairs may need to be adapted to the changed shape of the child.
- Management of transfers, including the hoist and slings, must be considered.
- All aspects of postoperative activities of daily living should be addressed preoperatively by an occupational or physical therapist.
- Bracing may still be required after surgery, and it requires an experienced orthotist. Support of the head may also be needed.
- Pain management is needed.
- Long-term follow-up by spinal surgeons is needed given the child's changing status.
- Increasing hyperextension of the neck is common in this group of disorders and needs to be monitored; strategies must be developed to alleviate the concomitant problems of function. Extension of the spinal surgery into the neck may be required.

Cardiological Care

Congenital muscular dystrophies can be associated with severe cardiac complications that increase morbidity and mortality.

These cardiac complications are frequently overlooked and are detected only late in the course of the disease. Systematic cardiac screening allows early diagnosis and treatment and improves patient prognosis. The global management strategy should be preventive rather than curative.

Literature Review

LMNA mutations. Patients with laminopathies have a high risk of developing cardiac disease. Primary myocardial involvement is frequent, with most patients suffering a dilated cardiomyopathy that can be associated with severe heart failure.[75-77] Disease onset can occur before 1 year of age. Ventricular arrhythmias, conductive defects, and supraventricular arrhythmias are frequent. Sudden cardiac death has been reported in several patients, probably in relation to severe ventricular arrhythmias. The 2 main issues in patients with laminopathies are early detection of ventricular dysfunction and prevention of sudden death.

Dystroglycanopathies. Myocardial involvement is frequent in patients with dystroglycanopathies. Dilated cardiomyopathy has been frequently reported in patients with mutations in the *FKRP* gene before the age of 5 years[78,79] and in patients with Fukuyama congenital muscular dystrophy in the second decade of life.[80,81] Cardiac disease has not been reported in patients with Walker-Warburg syndrome and muscle–eye–brain disease. However, those patients should be considered at risk to develop similar complications because they share a similar pathway with an abnormal dystroglycan glycosylation that is also present in the myocardium. Severe arrhythmias have not been reported in patients with dystroglycanopathies. The main issue in patients with dystroglycanopathies is the early detection and treatment of myocardial dysfunction.

MDC1A. Left ventricular dysfunction has been reported in approximately one third of patients with MDC1A.[4] The majority of patients did not complain of any symptom. However, severe heart failure has also been reported in both children and adults.[4,82-84] The main issue in patients with MDC1A is the early detection and treatment of myocardial dysfunction.

COL6 diseases. Patients with Ulrich congenital muscular dystrophy and Bethlem myopathy do not appear to have an increased risk of cardiac involvement.[85,86]

SEPN1 mutations. Primary cardiac involvement has not been reported in patients with SEPN1 mutations. However patients with severe respiratory failure can develop cor pulmonale, right heart failure, and pulmonary hypertension.[87-89]

Cardiology Care Recommendations

Diagnostic strategy. We recommend that all patients with congenital muscular dystrophies undergo cardiac screening and that investigations be started at diagnosis. The initial evaluation can help with diagnosis of the type of congenital muscular dystrophy, provides reference values for follow-up, and assists

follow-up planning. The most frequently reported symptoms are lethargy, dyspnea, pallor, palpitations, syncope, and light-headedness. Right heart failure can reveal as cor pulmonale. Cardiac disease symptoms sometimes are atypical, particularly in the youngest patients, and can start late in the course of disease. This observation supports the fact that cardiac examinations should be systematically performed. The frequency of follow-up depends on the presence of cardiac risk factors such as diagnosis of laminopathy or dystroglycanopathy, cardiac symptoms, and abnormal previous cardiac tests. In patients with laminopathies or dystroglycanopathies, cardiac examinations should be performed at least every year. These should be performed at least every 6 months in patients with symptoms, conductive abnormalities, or myocardial involvement. In patients with other congenital muscular dystrophies, follow-up should be performed at least every 2 years in asymptomatic patients and at least every year in patients with cardiac symptoms.

Cardiac investigations should be systematically performed at diagnosis and during follow-up. Electrocardiography and echocardiography are simple examinations and provide enough information in the majority of patients. Twenty-four-hour ambulatory electrocardiogram should be considered in patients with laminopathies in order to detect paroxysmal conductive defects and arrhythmias. Isotopic ventriculography can be useful to assess ventricular function in patients with poor echogenicity due to thoracic deformations. Cardiac magnetic resonance imaging could be useful in patients with laminopathies.

Treatment for cardiac symptoms in congenital muscular dystrophy. In regard to ventricular dysfunction, left ventricular ejection fraction below 50% should be considered abnormal in patients with congenital muscular dystrophy. Since worsening of ventricular dysfunction is observed in a majority of patients, prompt medical treatment should be initiated even in patients with mild ventricular dysfunction. There was a consensus on the fact that angiotensin-converting enzymes and β-blockers are the most appropriate cardioprotective drugs. The management of patients with severe ventricular dysfunction and/or heart failure symptoms does not differ from the management of the general pediatric population.

Supraventricular arrhythmias can develop in patients with laminopathies. Treatment should theoretically include anticoagulants to prevent thromboembolic complications and drugs that slow heart rate or are antiarrhythmic. However, anticoagulant therapy is complicated in patients with congenital muscular dystrophies, particularly in young children and in patients who could fall. This increases the risk of bleeding complications. The first-line antiarrhythmic treatment should be β-blockers.

Severe ventricular arrhythmias can be present in patients with *LMNA* mutations and can lead to sudden death. Since the number of reported patients remains low, risk factors for sudden death have not been identified. An implantable cardioverter defibrillator is the only treatment demonstrating efficacy in preventing sudden cardiac death in patients with *LMNA* mutations.[90] In secondary prevention, after a resuscitated sudden death or a sustained ventricular tachycardia, the use of an implantable cardioverter defibrillator is highly recommended. In primary prevention, the use of a cardioverter defibrillator should be considered in patients with cardiac symptoms, such as syncope or palpitations, severe conductive disease, left ventricular dysfunction, or significant functional or morphological right ventricular abnormalities. An implantable cardioverter defibrillator is feasible in young patients, even in those aged less than 1 year.[91] However, it is technically difficult in a high proportion of patients because of extreme thinness or major deformities of the chest wall. Subcutaneous lead implantation array can be necessary, particularly in the youngest patients.

Palliative Care

Palliative care is an interdisciplinary model integrating emotional, spiritual, developmental, and physical dimensions into the care of individuals with life-threatening diseases. Health care providers should educate patients and families that palliative care is complementary to care with curative intent and that incorporating palliative care principles during ongoing therapies will improve support systems during illness and for loved ones after death.[92] Comprehensive care for congenital muscular dystrophies should encompass the entire life span, and a clear distinction should be made between a "life-limiting" diagnosis and a "life-threatening" episode, considering that the trajectory of life toward death will be highly variable and certainly individual (see Figure 3). Incorporating palliative care from diagnosis can benefit the patient, family, and medical team as they anticipate and make decisions regarding interventions that affect both the duration and quality of these individuals' lives.

The Congenital Muscular Dystrophy Family Survey data show that there is wide variability in the point of introduction of palliative care to the patient and family as well as in the availability and composition of palliative care teams to assist with the complex needs of patients with congenital muscular dystrophy. Ideally, palliative care is an ongoing part of disease management in parallel with other areas of care. End-of-life discussions should be individualized and, especially for the more severe life-limiting congenital muscular dystrophy diagnoses (eg, Walker-Warburg syndrome), should occur before the first life-threatening event. Results of the congenital muscular dystrophy Family Standard of Care survey indicate that families prefer to be made aware of potential outcomes of the congenital muscular dystrophy diagnosis across medical disciplines, not just with end-of-life discussions. Visually presenting life trajectories as shown in Figure 3 could help families understand that congenital muscular dystrophy can cause life-threatening episodes in the context of a potentially life-limiting disease, and this information can serve as a platform to discuss choices that are available for common life-threatening complications before they occur.

Defining the Palliative Care Team. Established inpatient and outpatient palliative care resources should be used if available; however, various members of the multidisciplinary team can provide palliative care and support the child/adolescent and family.

Importance of Care Coordination. Care coordination of all modalities of care (irrespective of whether the patient's health is improving, remaining stable, or deteriorating) is essential in the complex context of congenital muscular dystrophy and should be orchestrated by a designated member of the team with whom the patient/family has direct contact. This can be a nurse, nurse practitioner, physician's assistant, or other team member who is knowledgeable of the issues involved in congenital muscular dystrophy and is capable of complex decision making. Coordinating care and communication between various disciplines is challenging for families and can be enhanced by a clinical professional while including patients and families as active participants in their care and decision-making processes.

Pain in Congenital Muscular Dystrophies. Pain is often multifactorial and can be a significant and underrecognized problem in congenital muscular dystrophy. Pain can include musculoskeletal (eg, contractures, fractures, muscle weakness/strain, scoliosis), neuropathic (eg, progressive kyphoscoliosis), respiratory (eg, chest wall, infection, ischemic), cardiac, gastrointestinal (eg, malnutrition, medications, stress), iatrogenic (eg, poorly fitting supportive apparatus such as splints, wheelchairs), and existential suffering. Effective management begins with a comprehensive assessment of acute and chronic pain to determine the presence, frequency, and duration of painful episodes and to identify alleviating or exacerbating factors.[71,93] Coexisting psychological states such as fear and anxiety, depression, and other causes of stress need to be explored and managed.

Fatigue in Congenital Muscular Dystrophies. Fatigue was reported commonly in the patient/family survey, but no systematic studies have explored the frequency of fatigue in congenital muscular dystrophy. Additional factors to consider include activity level, respiratory status, sleep hygiene, and medications.[71,93] Although stimulants (eg, caffeine, methylphenidate, and dextroamphetamine) have been used to treat fatigue in other diseases, the use of stimulants in muscular dystrophies has not been studied.

Aspects of Mental Health. Children with congenital muscular dystrophy and their families seem particularly vulnerable to depressive illness and increased levels of anguish due to the often complex and laborious steps to establish a molecular diagnosis, the extreme variability of clinical disease forms, and uncertain prognoses and disease trajectories, although this remains an area of further study. If the disease type is unknown, children and parents can feel that they do not have the disease in question and that a cure is possible. Although achieving diagnostic certainty can be satisfying, the affected child can feel overwhelmed and isolated and exhibit depressive reactions directly (ie, sadness) or indirectly (ie, anger, restlessness), although similar issues are of concern even in the absence of a molecular diagnosis confirmation. Families and children need early, developmentally appropriate psychological consultations to assess the intensity of their distress and to discuss resources for coping, in an attempt to achieve the highest functional capacity.[94,95] Consultations facilitate open discussion, relationship building, and the release of tension and anguish and enable patients and family members to plan effectively for the future when a prognosis is unclear and a child's life span is limited.

Improved Management in Changing the Prognosis of Congenital Muscular Dystrophy. Recent advances in supportive pulmonary, orthopedic, and cardiac care for patients with neuromuscular disorders have significantly affected prognosis, long-term management, and rates of survival; however, these interventions can make it even more difficult to predict outcome and life expectancy in patients with congenital muscular dystrophy. Even if a definitive diagnosis cannot be established, despite a thorough workup, this should not interfere with the ability to individually manage the variety of medical problems arising in patients with congenital muscular dystrophy. Providing well-coordinated multidisciplinary care and creating strong provider–patient relationships and individualized care plans are essential throughout the changing course of the disease. Primary care providers should be included in care to ensure that children's developmental and primary care needs are met.

End-of-Life Care. Family members and providers often find it difficult to discuss the possibility of death, and the timing of end-of-life discussions varies in the context of disease severity, unclear diagnoses, and uncertain prognoses. Opportunities for discussion commonly arise with deterioration of the child's physical status or during a medical emergency; however, it is the responsibility of providers to initiate this discussion and to provide families with information regarding options for care. This should happen before the occurrence of a major life-threatening event, allowing families time to clearly explore options and gather information before a decision must be made.

Regardless of who initiates the conversation, the goal is to partner with families and to present them with information in a developmentally appropriate and culturally sensitive manner, while elucidating that their choices may change at any time. A written plan should be developed that clearly states the parents' and child's wishes for both emergency situations and slower illness deterioration, as this will allow families to feel more in control during these times. The opportunity to contribute to research through tissue donation can empower families by enabling them to contribute to the further understanding of congenital muscular dystrophy. Following the death of a child, families should be presented with bereavement resources and teams should establish a standard practice for supporting families following the death of their child, as many families choose to remain in contact with the care team.
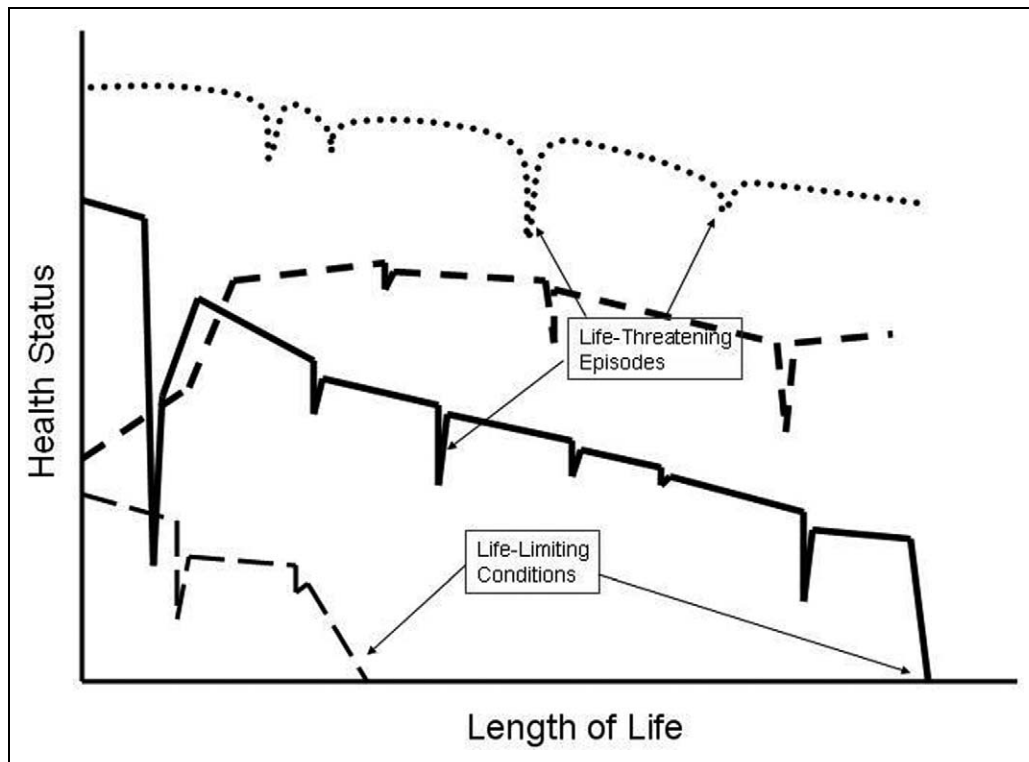
Figure 3. Trajectories of chronic illness through the life span. This figure represents disease trajectories of 4 fictional children living with congenital muscular dystrophy from birth throughout their life span. Life-limiting conditions permeate each child's life as represented by the 4 lines above, whereas life-threatening episodes, represented by dips in the lines, occur intermittently throughout the trajectory of each child's life. The life-limiting disease serves as the platform to discuss available choices for life-threatening complications before they occur. The figure also depicts that health status can improve after each life-threatening episode with a variable overall decline in the life trajectory.

Self-Care of the Health Care Provider. Providing children, adolescents, and family members with palliative care gives health care providers the unique opportunity to support families during what is often the most difficult time of their lives. Although rewarding, this type of work is difficult by nature and is often taxing. Therapeutic support for providers can be offered in the hospital or university setting and should be made available either on a regular basis or, at minimum, surrounding the time of a patient's death. Every team should incorporate a plan of support for its providers.

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The authors declared no potential conflicts of interest with respect to the authorship and/or publication of this article.

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