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Family doctor and paediatrician care for a patient with spinal muscular atrophy

Opieka lekarza rodzinnego i pediatry nad pacjentem z rdzeniowym zanikiem mięśni

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Abstract

Spinal muscular atrophy (SMA) is a neurodegenerative disease leading to motor disability, progressive respiratory failure and ultimately death. Its incidence is estimated at approximately 1/7,600 births in the Polish population. Owing to effective, modern treatment methods, SMA may be nowadays considered a chronic disease. Early and effective diagnosis based on newborn screening, followed by the implementation of one of the three available therapies, makes it possible to slow down the disease progress and to acquire further motor development skills by patients. Comprehensive care including nutrition, diagnosis of respiratory, gastrointestinal, and musculoskeletal disorders, and rehabilitation remain a challenge for the health care system. In the paper we discuss basic issues on the aetiology, inheritance patterns and typical clinical picture of SMA, the principles of neonatal screening in Poland, the treatments available as part of the drug therapy program (nusinersen, risdiplam, onasemnogene abeparvovec), as well as everyday care and health prevention in patients diagnosed with SMA. Special attention was paid to physiotherapy and motor improvement. An important task of primary care physicians is to actively search for possible complications of the disease and adverse effects of treatment methods, and to implement the vaccination programme. Individuals with SMA will constitute an increasing percentage of patients in general practice offices, which is why close cooperation between general practitioners, paediatricians and neurologists is extremely important to ensure comprehensive and coordinated care.

Keywords: spinal muscular atrophy, rehabilitation, gene therapy, newborn screening

Streszczenie

Rdzeniowy zanik mięśni (*spinal muscular atrophy*, SMA) w swoim naturalnym przebiegu jest chorobą neurodegeneracyjną, prowadzącą do niepełnosprawności ruchowej, postępującej niewydolności oddechowej i ostatecznie zgonu. Szacuje się, że częstość występowania tej choroby w populacji polskiej wynosi około 1/7600 urodzeń. Obecnie skuteczne, nowoczesne metody leczenia pozwalają traktować SMA jako chorobę przewlekłą. Wczesna i efektywna diagnostyka prowadzona w oparciu o noworodkowy przesiew populacyjny, a następnie wdrożenie jednej z trzech dostępnych terapii umożliwia spowolnienie procesu chorobowego i nabywanie przez pacjentów kolejnych umiejętności rozwoju ruchowego. Kompleksowa opieka dotycząca odżywienia, diagnozowania zaburzeń układu oddechowego, pokarmowego i mięśniowo-szkieletowego oraz rehabilitacji pozostaje wyzwaniem dla systemu ochrony zdrowia. W artykule omówiono podstawowe zagadnienia dotyczące etiologii i dziedziczenia SMA, typowego obrazu klinicznego choroby, zasad funkcjonowania w Polsce badań przesiewowych noworodków, terapii dostępnych w ramach programu lekowego (nusinersen, rysdyplam, onasemnogen abeparwowek), a także codziennej opieki nad pacjentami z rozpoznaniem SMA i stosowanej u nich profilaktyki zdrowotnej. Ważnym zadaniem lekarzy podstawowej opieki zdrowotnej jest aktywne poszukiwanie możliwych powikłań choroby i działań niepożądanych stosowanych leków oraz realizowanie programu szczepień. Pacjenci z SMA będą stanowić coraz większy odsetek chorych w gabinetach lekarzy rodzinnych, dlatego wyjątkowo istotna jest ścisła współpraca pomiędzy lekarzami rodzinnymi, pediatrami i neurologami w kwestii pełnej i skoordynowanej opieki.

Słowa kluczowe: rdzeniowy zanik mięśni, rehabilitacja, terapia genowa, badania przesiewowe noworodków

INTRODUCTION

Spinal muscular atrophy (SMA) is a neurodegenerative, inheritable disease with progressive weakness of muscles due to degeneration of the alpha motor neurons of the spinal cord anterior horn cells[1]. The proximal muscle groups of the upper and lower limbs are initially involved, followed by the respiratory muscles, ultimately leading to death in the natural course of the disease. Over the past decade, enormous progress has been made in the treatment of SMA, changing its status from a potentially fatal to chronic disorder.

The estimated global incidence of SMA is 1/11,000 births. The disease is inherited in an autosomal recessive manner, with one in 40–67 people being carriers of a mutated copy of the *SMN1* (surviving motor neuron 1) gene[2]. The introduction of universal newborn screening allowed to estimate the incidence of SMA in Poland at about 1 in 7,000 births, which is consistent with the data for the German population (1:6,910)[3,4].

At a molecular level, SMA is caused by a biallelic deletion of exon 7 of the *SMN1* gene located on the long arm of chromosome 5 (5q11.2–q13.3) in the vast majority of cases (approximately 96%). The mutation ceases the production of functional SMN protein, which is necessary for the proper functioning of motor neurons. The *SMN2* gene, a paralog of the *SMN1* gene located in the centromeric area of the same chromosome, allows for producing a small amount of stable SMN protein[5]. The number of *SMN2* copies varies among SMA patients, and when it is multiplied (e.g. via the duplication mechanism), delayed symptom onset and their slower progress are usually observed[6]. Point mutations are responsible for SMA in only a small percentage of cases.

SMA has been classified into five types based on the clinical course and age at disease onset. Type 0 is a rare and the most severe form with the earliest onset. Mothers of children with this type of SMA usually report decreased foetal movements, and these children are born with severe hypotonia, respiratory failure and the need for mechanical ventilation. Children with type 1 SMA (the most common) experience symptom onset in the first six months of life. As a result of rapidly increasing muscle weakness, patients do not reach the milestone of sitting independently, and if left untreated, they usually require invasive ventilation in the second six months of life[7]. This type of SMA was until recently considered the most common genetic cause of early infant death. Children with SMA type 2 reach the developmental milestone of sitting independently, but cannot walk unassisted, and the onset of symptoms is usually between 7 and 18 months of age. In SMA type 3, the first symptoms appear after walking begins, and in the rare type 4, muscle weakness occurs in adulthood[8].

Currently, owing to screening tests and the possibility of implementing treatment before obvious clinical symptoms occur, the described classification is becoming historical. Patients with SMA live much longer and their quality of life is improving. However, the need to organise multidisciplinary care and face the problems typical of patients with chronic neuromuscular disease remains a challenge. The aim of this paper is to introduce general practitioners and paediatricians to issues related to the care of SMA patients.

UNIVERSAL NEWBORN SCREENING

In accordance with the Governmental Newborn Screening Programme, SMA screening began in April 2021. Subsequent provinces were gradually included in the screening, with all Polish newborns covered by the screening programme from April 2022. As in other screening tests (e.g. for cystic fibrosis or phenylketonuria), capillary blood is collected onto filter paper on day 3 of life. The first step is to perform the DNA amplification using the polymerase chain reaction (PCR) supplemented by high-resolution melting (HRM), which allows for the detection of a homozygous deletion of exon 7 of the *SMN1* gene in the tested blood. Due to the risk of false positive results, MLPA (multiplex-ligation dependent probe amplification) verification is performed for invalid or questionable samples[9]. The inability to differentiate between heterozygous deletion and a point mutation of the second allele is a limitation of the screening. It is therefore estimated that 1–2 SMA children will be missed in screening per year in Poland. The Screening and Metabolic Diagnostics Department and the Medical Genetics Department of the Institute of Mother and Child in Warsaw are institutions responsible for performing the analyses. Almost 106,000 newborns had been screened by 7 June 2024, including 103 positive tests, which allowed to estimate the incidence of SMA at 1 in 7,602 (data not published yet, obtained by courtesy of Professor Monika Gos). Positive tests are reported to provincial diagnostic and treatment centre in the patient's place of residence or the nearest neighbouring province, which immediately notifies the parents and invites them to report with the child to the hospital to discuss the result, perform clinical evaluation and collect venous blood samples for verification. The list of centres is available on the websites of the National Health Fund (Narodowy Fundusz Zdrowia, NFZ) and the SMA Foundation[10]. The screening results are available around 8 days of the child's life (median; *SD* 3.65), the confirmatory test is available on day 14 (median; *SD* 4.94; data by courtesy of Professor Monika Gos). According to Polish law, written consent from a parent or legal guardian is needed to perform all of the analyses described (genetic tests). It should be remembered that in the case of home births, the blood is collected by the midwife attending the delivery or community midwife/nurse, and the proper outpatient screening should be supervised by a general practitioners (GP). According to the assumptions of the European Alliance for Newborn Screening in Spinal Muscular Atrophy, all European countries should be included in screening by the end of 2025[11].

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THERAPEUTIC OPTIONS FOR SMA PATIENTS

At the beginning of 2019, the first Polish drug programme for SMA patients was launched, enabling treatment with nusinersen. Since 1 September 2022, the programme has been expanded and three therapies are currently reimbursed by the NFZ: in addition to the already mentioned nusinersen, risdiplam and onasemnogene abeparvovec can be used (Tab. 1)[12]. Each of these drugs increases SMN levels.

Nusinersen has been used in clinical practice for the longest time. The mechanism of action of this antisense oligonucleotide (ASO) is to increase exon 7 inclusions in survival motor neuron 2 (*SMN2*) mRNA transcripts. By binding to the intronic splicing silencer site in pre-mRNA, the drug displaces splicing factors, which ultimately keeps exon 7 in the *SMN2* mRNA and enables the production of a functional SMN protein. Nusinersen cannot cross the blood–brain barrier and is thus administered intrathecally, by lumbar puncture[13]. The initial, so-called loading doses, are given on days 0, 14, 28 and 63, and then every 4 months. The recommended dose is 12 mg (5 mL), independently of the patient's body weight. Patients are usually admitted for a one-day hospital stay to run basic tests to exclude possible contraindications to lumbar puncture, and after drug administration and observation, they are discharged home. The administration of nusinersen can be technically challenging, especially in patients with severe scoliosis or obesity, and usually requires light sedation. The most common adverse reactions are related to the drug administration and include post-puncture headaches, vomiting, and back pain. When qualifying a patient for nusinersen treatment, peripheral blood counts, aminotransferase activity, and coagulation parameters should be assessed, as well as urinalysis should be done.

A similar mechanism of action is exhibited by risdiplam, which corrects the *SMN2* pre-mRNA splicing process. It is available as an oral suspension administered once a day after a meal, with the dosage depending on body weight (0.15 mg/kg in children under 2 months of age, 0.20 mg/kg in children up to 2 years, 0.25 mg/kg in older children and 5 mg for 20 kg). Common adverse reactions include diarrhoea, rash, headache and fever. Before commencing treatment, patients routinely undergo basic laboratory tests: blood count with differential, aminotransferase activity and bilirubin.

Treatment	Nusinersen	Risdiplam	Onasemnogene abeparwowek
Type	Antisense oligonucleotide	Small molecule	AAV9-based gene therapy
Mechanism of action	Increases SMN protein production by influencing *SMN2* splicing		Delivers a functional *SMN* transgene
Route of administration	Intrathecal	Oral	Intravenous
Dosage	4 loading doses, then every 4 months	Every day	Single dose
The need for glucocorticoids	No	No	Yes

Tab. 1. Available treatment methods for SMA

In contrast to the two described drugs, onasemnogene abeparvovec is a single-dose, intravenous therapy administered at a dose dependent on body weight. The human SMN transgene is delivered in the capsid of AAV9 (adeno-associated virus 9), residing as episomal DNA in the nucleus of motor neurons, and providing an alternative source of long-term SMN protein expression[13]. AAV9 can cross the blood-brain barrier and is not pathogenic to humans. Anti-AAV9 titres (the drug is not administered in patients with titres >1:50), aminotransferase activity, bilirubin, platelet count and troponin I are measured before administrating onasemnogene abeparvovec. The most frequently reported adverse reactions include transient increases in hepatic aminotransferase activity, vomiting, thrombocytopenia, fever and elevated troponin I. In order to reduce the risk of hepatotoxicity, glucocorticoids are used at a dose equivalent to 1 mg/kg of prednisolone for a month, starting from the day preceding the drug administration, and then gradually reduced.

SMN2 copy number is one of determinants for therapeutic decisions. Patients with ≤ 3 *SMN2* copies can receive any of the three drugs mentioned. Nusinersen or risdiplam may be given to patients with 4 *SMN2* copies who also meet the other qualification criteria[14]. Detailed qualification criteria for each treatment are available in the current appendix to the SMA drug programme (B.102.FM).

All of the above-mentioned therapies have shown high efficacy confirmed in several clinical trials and by the real-world evidence (RWE)[15,16]. Regardless of the type of treatment used, the time of its implementation is extremely important, as emphasised by the term "time is motor neuron" that can be found in the literature, which also illustrates the neurodegenerative nature of the disorder[17].

Myostatin inhibitors (including apitegromab and taldefgrobep) have been a relatively new group of drugs used as adjunctive therapy. Myostatin is a protein from the family of growth differentiation factors (GDFs) responsible for controlling the growth of muscle tissue. Therefore, the inhibitor increases muscle mass. The preliminary results of ongoing clinical trials are promising[18].

THE ROLE OF THE GP AND PAEDIATRICIAN IN THE CARE OF A CHILD WITH SMA

It is of key importance that GPs are familiar with SMA symptoms. In the coming years, GPs and paediatricians will continue to provide care to children who are not included in newborn screening due to their age, deliberate resignation from the test, or its false negative result (among other things due to the presence of point mutations). The presence of the

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following symptoms should prompt the physician to extend the diagnosis, refer the patient to a paediatric neurologist or to hospital if significantly severe abnormalities occur:

- delay or failure to achieve gross and fine motor milestones;
- loss of previously achieved milestones;
- weakness of proximal limb muscles;
- hypotonia, weak limb movements, "frog" position, inability to lift head;
- fatigue during feeding;
- quiet crying;
- lack of tendon-periosteal reflexes;
- finger tremors and tongue fasciculations.

Patients diagnosed with SMA who are included in the treatment programme are regularly monitored by doctors from their treatment centres. However, it should be remembered that a GP is a specialist handling patients with developmental problems, infections or the need for active prevention of infections. In order to develop practical treatment standards, SMA patients have been classified as walkers, sitters and non-sitters[19].

In terms of nutrition, the role of a GP is primarily to regularly monitor weight and height gains. The use of SMA-specific growth percentile charts may be considered in children with long-term history of the disease and severe symptoms[20]. Dietary recommendations for walking children do not differ significantly from the advice in the healthy population; however, special attention should be paid to obesity prevention and vitamin D supplementation. In contrast, non-sitters often develop dysphagia and require nutritional, gastroenterological and dietetic care, as well as feeding with a gastric tube or percutaneous endoscopic gastrostomy (PEG). Constipation is a common problem, in which case pharmacological treatment includes the use of macrogols, phosphates enema and, optionally, lactulose.

Respiratory symptoms of SMA become particularly evident during infection. Recurrent symptoms of respiratory infection should raise a suspicion of aspiration[19]. Respiratory screening in non-sitters primarily includes physical examination and non-invasive measurement of blood oxygen using a pulse oximeter. In the case of suspected hypoventilation, capnometry and polysomnography are used as part of detailed diagnosis. Some patients require non-invasive positive pressure ventilation, usually initially at night and during infection, or constant ventilation through a tracheostomy tube. In addition to manual therapy, cough assisters are used in physiotherapy. Sitting and walking children are assessed for cough effectiveness, and recommended spirometry as part of specialist check-ups.

Orthopaedic problems mainly include spinal and thoracic deformities, joint contractures and hip instability[21,22]. Scoliosis occurs primarily in patients with SMA type 1 and 2, and its incidence in untreated children is estimated at 60–90%[23]. Posture assessment should be a routine element of check-ups in patients with family history of SMA. Bone densitometry is recommended as part of the extended diagnosis.

In cases of doubt, the attending GP should have the contact details of a centre responsible for treating the patient. It is good practice to include data on the diagnosis and treatment used, as well as the contact details of the treatment centre in the child's medical record book.

ACTIVE PREVENTION OF DISEASES IN CHILDREN WITH SMA

Although SMA is a progressive neurodegenerative disorder, it is crucial to implement the current Vaccination Programme in this group of patients[24]. It is recommended to administer diphtheria–tetanus–acellular pertussis vaccine (DTPa), polyvalent vaccines (5-in-1 or 6-in-1 vaccine), as well as additional vaccinations against meningococci (group B, groups A, C, W-135, and Y), chickenpox and annual vaccinations against influenza.

Patients treated with nusinersen and risdiplam should be immunised according to general rules. According to the Polish Society of Vaccinology, at least a two-week interval should be maintained between BCG vaccination and gene therapy due to the need to combine it with glucocorticoids in patients receiving onasemnogene abeparvovec[25]. Other attenuated (so-called live) vaccinations are also not recommended during steroid therapy. Therefore, the rationale behind vaccination against rotaviruses should be considered. Once glucocorticoid treatment is completed, there are no contraindications to active immunisation with live vaccines.

From the beginning of April 2024, the group of patients eligible for the RSV infection prevention programme using palivizumab has been expanded to include SMA children up to 2 years of age, regardless of the treatment used.

REHABILITATION OF SMA PATIENTS

Since the introduction of pharmacological treatment for SMA patients, there has been much evidence showing that appropriately adjusted and regularly applied physiotherapy can have a beneficial effect on slowing down disease progression. It is believed that the functional loss in SMA patients may be related to increasing joint contractures, significant and dynamic increase in scoliosis or excessive weight gain[26]. Therefore, physiotherapy in SMA should be tailored to the individual needs and functional status of the patient, taking into account the benefits of using orthopaedic devices, orthoses and individualised exercises[27,28].

In the group of children without clinical symptoms of SMA, the aim of physiotherapy is to maintain the child's asymptomatic status and individualised neurostimulation of development. For this purpose, physiotherapeutic approaches involving early developmental support are recommended, such as maintaining proper body symmetry, exercises to build proper muscle tone and respiratory efficiency, and to support verticalisation and the ability to walk correctly. In the case of significant deformities of the feet and spine, the use of corsets and orthoses is advised[29].

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Non-sitters require physiotherapy for training the sitting position, using individually adapted seats and orthopaedic equipment in the form of corsets, as well as respiratory therapy, stretching exercises to minimise joint contractures, verticalisation and gait therapy using robotic assisted technologies. Additionally, the use of lower limb orthoses (e.g. night orthoses for at least 60 minutes) and the prevention of hip joint dislocations and scoliosis (using corsets), as well as chest physiotherapy are important in the prevention of muscle contractures[19,27,30].

It should be a particular goal of physiotherapy in sitting patients to build performance in this position, as well as to prevent scoliosis and deformations in the lower limbs. This may be achieved with regular use of corsets and ankle foot orthosis (AFO) or knee ankle foot orthosis (KAFO). Verticalisation training using verticalisers for at least 60 minutes per day is also advised, and strong recommendations include respiratory therapy, positioning the patient in individually tailored seats, as well as stretching and joint mobility exercises. Exercises to increase muscle capacity and strength are also used. Active or electric wheelchairs should be considered to improve or enable mobility. Additionally, gait therapy utilising, for example, robotic-assisted technologies, can play an important therapeutic role[30].

In the group of walking patients, a model of physiotherapy aimed at enhancing the aerobic capacity and muscle strength of the upper and lower limbs, as well as training and improving independent or assisted walking are recommended. Water physiotherapy, using cycloergometers or treadmills, as well as hippotherapy, yoga and technology-assisted physiotherapy are recommended. Respiratory therapy, as well as stretching exercises and increasing joint mobility should not be omitted. In the case of joint deformities or scoliosis, orthopaedic appliances in the form of orthoses and corsets are recommended[27,30].

Regular orthopaedic check-ups with X-ray and verticalisation using AFO or KAFO are recommended to prevent hip dislocations and scoliosis. In patients with scoliosis (Cobb angle: 15–20°), corsets and regular orthopaedic check-ups are recommended. The optimal frequency of physiotherapy in SMA patients is 3–5 days per week.

CARE FOR THE FAMILY OF AN SMA PATIENT

SMA patients need multi-specialist, long-term care, regular visits to doctors' offices and hospitals, as well as intensive rehabilitation, which often requires the involvement of the entire family and reorganisation of their daily lives.

Considering the autosomal recessive inheritance of the disease, it is necessary to provide genetic counselling to family members, patient's siblings in particular. Clinical genetic counselling may prompt prenatal diagnosis in the mother of the affected child to quickly implement treatment in the event of giving birth to an SMA child.

GPs and paediatricians play an extremely important role in the care of SMA patients. The survival time of these patients is significantly longer; however, new challenges occur with age. The success of and satisfaction with treatment require continuous and effective cooperation between the patient, the general practitioner and other specialists.

Conflict of interest

The authors do not report any financial or personal connections with other persons or organisations which might negatively affect the contents of this publication and/or claim authorship rights to this publication.

Author contribution

Original concept of study: PM. Collection, recording and/or compilation of data: PM, PK. Analysis and interpretation of data: PM, CW, AM, KMM. Writing of manuscript: PM, RR. Critical review of manuscript; final approval of manuscript: MF.

References

1. Mercuri E, Bertini E, Iannaccone ST: Childhood spinal muscular atrophy: controversies and challenges. Lancet Neurol 2012; 11: 443–452.
2. Sugarman EA, Nagan N, Zhu H et al.: Pan-ethnic carrier screening and prenatal diagnosis for spinal muscular atrophy: clinical laboratory analysis of >72 400 specimens. Eur J Hum Genet 2012; 20: 27–32.
3. Ogrodnik M, Chmielewski D, Szwinge A et al.: Doświadczenia polskich ośrodków zajmujących się leczeniem pacjentów z rdzeniowym zanikiem mięśni. Neurol Dziec 2021–2022; 31–32: 11–25.
4. Vill K, Schwartz O, Blaschek A et al.: Newborn screening for spinal muscular atrophy in Germany: clinical results after 2 years. Orphanet J Rare Dis 2021; 31: 16–53.
5. Lefebvre S, Bürglen L, Reboullet S et al.: Identification and characterization of a spinal muscular atrophy-determining gene. Cell 1995; 80: 155–165.
6. Wirth B, Brichta L, Schrank B et al.: Mildly affected patients with spinal muscular atrophy are partially protected by an increased *SMN2* copy number. Hum Genet 2006; 119: 422–428.
7. Mercuri E, Lucibello S, Perulli M et al.: Longitudinal natural history of type I spinal muscular atrophy: a critical review. Orphanet J Rare Dis 2020; 15: 84.
8. Chabanon A, Seferian AM, Daron A et al.: Prospective and longitudinal natural history study of patients with type 2 and 3 spinal muscular atrophy: baseline data NatHis-SMA study. PLoS One 2018; 13: e0201004.
9. Ministerstwo Zdrowia: Rządowy program badań przesiewowych noworodków w Polsce na lata 2019–2026. Available from: https://www.gov.pl/web/zdrowie/program-badan-przesiewowych-noworodkow-w-polsce-na-lata-2019-2026 [cited: 1 May 2024].
10. Fundacja SMA: Jednostki szpitalne prowadzące program lekowy. Available from: https://www.fsma.pl/leki/program-lekowy/szpitale/ [cited: 1 May 2024].
11. SMA NBS Alliance: About us. Available from: https://www.sma-screening-alliance.org/about-us [cited: 1 June 2024].
12. Ministerstwo Zdrowia: Obwieszczenie Ministra Zdrowia z dnia 18 marca 2024 r. w sprawie wykazu refundowanych leków, środków spożywczych specjalnego przeznaczenia żywieniowego oraz wyrobów medycznych na 1 kwietnia 2024 r. Available from: https://www.gov.pl/web/zdrowie/obwieszczenie-ministra-zdrowia-z-dnia-18-marca-2024-r-w-sprawie-wykazu-refundowanych-lekow-srodkow-spozywczych-specjalnego-przeznaczenia-zywieniowego-oraz-wyrobow-medycznych [cited: 1 May 2024].

 DOI: 10.15557/PiMR.2025.0002

13. Nicolau S, Waldrop MA, Connolly AM et al.: Spinal muscular atrophy. Semin Pediatr Neurol 2021; 37: 100878.
14. Blaschek A, Kölbel H, Schwartz O et al.: Newborn screening for SMA – can a wait-and-see strategy be responsibly justified in patients with four SMN2 copies? J Neuromuscul Dis 2022; 9: 597–605.
15. Day JW, Howell K, Place A et al.: Advances and limitations for the treatment of spinal muscular atrophy. BMC Pediatr 2022; 22: 632.
16. Erdos J, Wild C: Mid- and long-term (at least 12 months) follow-up of patients with spinal muscular atrophy (SMA) treated with nusinersen, onasemnogene abeparvovec, risdiplam or combination therapies: a systematic review of real-world study data. Eur J Paediatr Neurol 2022; 39: 1–10.
17. Govoni A, Gagliardi D, Comi GP et al.: Time is motor neuron: therapeutic window and its correlation with pathogenetic mechanisms in spinal muscular atrophy. Mol Neurobiol 2018; 55: 6307–6318.
18. Crawford TO, Darras BT, Day JW et al.: Safety and efficacy of apitegromab in patients with spinal muscular atrophy types 2 and 3: the phase 2 TOPAZ study. Neurology 2024; 102: e209151.
19. Mercuri E, Finkel RS, Muntoni F et al.: Diagnosis and management of spinal muscular atrophy: part 1: recommendations for diagnosis, rehabilitation, orthopedic and nutritional care. Neuromuscul Disord 2018; 28: 103–115.
20. De Amicis R, Baranello G, Foppiani A et al.: Growth patterns in children with spinal muscular atrophy. Orphanet J Rare Dis 2021; 16: 375.
21. Sporer SM, Smith BG: Hip dislocation in patients with spinal muscular atrophy. J Pediatr Orthop 2003; 23: 10–14.
22. Coratti G, Lenkowicz J, Pera MC et al.: Early treatment of type II SMA slows rate of progression of scoliosis. J Neurol Neurosurg Psychiatry 2022; 95: 235–240.
23. Lunn MR, Wang CH: Spinal muscular atrophy. Lancet 2008; 371: 2120–2133.
24. Yeşilmen MC, Günay Ç, Sarıkaya Uzan G et al.: Immunization status of patients with spinal muscular atrophy receiving nusinersen therapy. Arch Pediatr 2023; 30: 291–296.
25. Polskie Towarzystwo Wakcynologii: Stanowisko Zarządu Polskiego Towarzystwa Wakcynologii w sprawie szczepień BCG w związku z wprowadzeniem terapii genowej SMA. Available from: https://ptwakc.org.pl/2021/08/31/stanowisko-zarzadu-polskiego-towarzystwa-wakcynologii-w-sprawie-szczepien-bcg-w-zwiazku-z-wprowadzeniem-terapii-genowej-sma/ [cited: 1 May 2024].
26. Mercuri E, Finkel R, Montes J et al.: Patterns of disease progression in type 2 and 3 SMA: implications for clinical trials. Neuromuscul Disord 2016; 26: 126–131.
27. Yi YG, Shin HI, Jang DH: Rehabilitation of spinal muscular atrophy: current consensus and future direction. J Genet Med 2020; 17: 55–61.
28. Schorling DC, Pechmann A, Kirschner J: Advances in treatment of spinal muscular atrophy – new phenotypes, new challenges, new implications for care. J Neuromuscul Dis 2020; 7: 1–13.
29. Mercuri E, Sumner CJ, Muntoni F et al.: Spinal muscular atrophy. Nat Rev Dis Primers 2022; 8: 1–16.
30. Agyenkwa SK, Cibooğlu P, Jhar N et al.: Rehabilitation in spinal muscular atrophy: a narrative review. Eur J Ther 2023; 29: 656–666.

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