Hindawi Publishing Corporation
ISRN Anesthesiology
Volume 2013, Article ID 791983, 10 pages
http://dx.doi.org/10.1155/2013/791983

Review Article

Anesthetic Management in Mucopolysaccharidoses

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Received 18 April 2013; Accepted 14 May 2013

Academic Editors: F. Cavaliere, F. Khan, A. Mizutani, and A. Wiebalck

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Mucopolysaccharidoses (MPSs) are a group of uncommon genetic diseases of connective tissue metabolism. It is well established that the elective treatment of subjects affected by MPS is multidisciplinary and must be carried out by experienced personnel in highly specialist centers. However, there is the possibility to perform an anesthesia in a peripheral center, where anesthesiologists might not have a large experience of MPS. Various attempts to produce guidelines have been made for MPS. There has been an increasing interest in the topic as it is demonstrated by the number of scientific studies published in the last few years (peak in 2011). We want to provide a summary of anesthetic management, reviewing the current literature on the topic in a procedural algorithm for these high-risk patients, who require surgical procedures and diagnostic examinations under sedation with a higher frequency than the general population.

1. Introduction

The necessity of codified and univocal guidelines, suitable for all patients, is a common challenge in the field of rare diseases. The first difficulty arises from the lack of cases to study, so as to identify without excessive variety the clinical features of the conditions in study and from the consequent poor literature and the differences between worldwide centers in diagnosis, treatment, and management protocols. Various attempts to produce guidelines of this kind have been made for mucopolysaccharidoses (MPSs). There has been an increasing interest in the topic as it is demonstrated by the number of scientific studies published in the last few years (peak in 2011). It is well established that the elective treatment for subjects affected by MPS is multidisciplinary and must be carried out by experienced personnel in highly specialized centers. However, there is the possibility to perform an anesthesia for these kinds of pediatric patients in a peripheral center, where anesthesiologists might not have a large experience of MPS.

Our intent is to review the current literature on this topic in a procedural algorithm of anesthetic management for these high-risk patients, requiring surgical procedures and diagnostic examinations under sedation with a higher frequency than the general population. Particularly, we are focusing on perioperative (pre-, intra-, and post-) anesthetic management. Our final aim is to improve the quality of care offered and, as a consequence, the quality of life of subjects affected by MPS.

2. Mucopolysaccharidoses

Mucopolysaccharidoses are uncommon [1] genetic diseases related to the metabolism of connective tissue [2].

The lack or deficiency of specific lysosomal enzymes leads to the storage of partially degraded glycosaminoglycans (GAG: dermatan sulphate, heparan sulphate, or keratan sulphate) [2, 3] causing progressive cellular, organ, and multisystemic damage [4].

Classification of MPS disorders includes 7 major types (I–IX) on the basis of clinical features, age at presentation, and biochemical alterations (Table 1) [5–7].

The MPS group includes a wide range of clinical manifestations with differences in life span and quality of life. All types are autosomal recessive inherited [8], except type II [9], which is X-linked; all forms are characterized by distinct somatic manifestations [10] but not subjects with type III

Table 1: Classification of mucopolysaccharidoses.

Type	Denomination	Main clinical features	GAGS*	Enzyme deficiency
MPS IH	Hurler syndrome	Severe phenotype, macrocephaly, macroglossia, facial coarseness, hydrocephalus, mental retardation, joint stiffness, thoracic and lumbar kyphosis, possible odontoid hypoplasia.	DS, HS	α-L-Iduronidase
MPS IS	Scheie syndrome	Joint stiffness, corneal turbidity, aortic valve disease, normal intellectual capabilities, macroglossia, normal stature, living until adulthood.	DS, HS	α-L-Iduronidase
MPS I H/S	Hurler-Scheie syndrome	Intermediate phenotype, macrocephaly, macroglossia, joint limitations.	DS, HS	α-L-Iduronidase
MPS II	Hunter Syndrome	Severe course MPS I H-like, moderate course-clinical intermediate phenotype, late manifestations, living until adulthood with or without mental retardation.	DS, HS	Iduronate-2-sulfatase
MPS III A	SanfilippoA syndrome	Behavior disorders, aggressiveness.	HS	Heparan-N-sulfatase
MPS III B	SanfilippoB syndrome	Progressive dementia, living until the second and third decade.	HS	α-N-acetyl-glucosaminidase
MPS III C	SanfilippoC syndrome	Remarkable interfamilial variability, mild dimorphism.	HS	AcetylCoA:a-glucosaminide acetyltransferase
MPS III D	SanfilippoD syndrome	Rough hair, limpid cornea, usually normal height.	HS	N-acetilglucosamine-6-solfatase
MPS IV A	MorquioA syndrome	Short trunk dwarfism, thin corneal opacities, skeletal dysplasia and spondylo epiphyseal, final height under 125 cm.	KS	N-acetilglucosamine-6-solfatase
MPS IV B	MorquioB syndrome	Idem MPS IV A, adulthood height under 120 cm.	KS	β-galactosidase
MPS VI	Maroteaux-Lamy syndrome	Hurler phenotype with pronounced corneal opacities and normal intellectual capabilities.	DS	N-acetylgalactosamine 4-sulfatase
MPS VII	Sly syndrome	High phenotypic variability, dense granulocyte inclusions, macrocephaly, possible odontoid hypoplasia, shortness.	CS, DS, HS	β-glucuronidase

*DS: dermatan sulphate, HS: heparin sulphate, KS: keratin sulphate, and CH: chondroitin-6-sulphate.

(Sanfilippo) [11]; moreover, progressive mental retardation is always present in severe forms of types I, II (Hurler, Hunter), and VIII (Sly). Type III, due to the marked central nervous system (CNS) involvement, can be affected by severe mental retardation as well as aggressive behavior, hyperactivity, sleep problems, and loss of the capacity to perceive dangers [12, 13].

In spite of the severity of their somatic presentation types, IV and VI have no mental impairment [14–17]. However, patients with severe somatic affections may show a higher degree of neurological involvement than they actually have, due to the language disturbance coming from decreased hearing, enlarged tongue, poor vision, reduced manual skills, consequences of joint stiffness, and respiratory insufficiency.

MPS subjects require frequent surgical and diagnostic anesthetic procedures or sedations. They are common operations, including herniorrhaphy, adenotonsillectomy, and median nerve decompression; on the other hand, others demand nonroutine procedures such as cardiac valve replacement, spinal cord decompression, ventricular peritoneum shunt, and orthopedic surgery to rectify deformations and skeletal defects [18] (Table 2).

3. Clinical Manifestations and Anesthetic Risk

Every MPS type is characterized by progressive craniofacial, articular, and skeletal deformities, cardiac involvement, and early death due to pulmonary infections or heart failure, often before adulthood (Table 3).

Patients usually look normal at their birth but progressively develop clinical manifestations according to the kind of syndrome they are affected by [19].

The management of these situations is a challenge for the anesthesiologist. The anesthetic risk of MPS patients must be considered high for many reasons, including airway abnormalities, orthopedic deformities, pulmonary predisposition, and cardiac and neurological involvement (Table 4).

Operative risk is higher in I, II, IV, and VI types (overall mortality rate is 20%) [4, 20]; particularly, MPS IH is

Table 2: Main associated clinical conditions and possible treatment.

Associated medical conditions	Surgical clinical conditions
Mental retardation (MPSIH, MPSII, MPSIII) [32]	Communicating hydrocephalous → ventricular peritoneal shunt (especially MPSI, MPSII, and MPSIIIA) [32] *AIEOP-SIMMESN/recommendations MPS I/25.10.2010*
Seizures (MPSI, MPSII) [12] *AIEOP-SIMMESN/recommendations MPS I/25.10.2010*	Spinal cord compression → Decompression and rachis stabilization (common to all MPS syndromes except MPSIII e MPSIX) [32–34]
Joint stiffness (common to all MPS syndromes except MPS IV, with ligamentous laxity prevalence) [32]	Skeletal deformities: kyphoscoliosis, valgus and varus limbs, and carpal tunnel → Corrective orthopedic surgery (especially in MPSII, MPSIV) [32, 35]
Glaucoma (common to all MPS types) [32, 36]	Corneal opacity → corneal transplantation (especially MPSI, MPSIV, MPSVI, and MPSVII) [32, 33, 37] *AIEOP-SIMMESN/recommendations MPS I/25.10.2010*
Retina degeneration (especially MPSI, MPSII, and MPSIII) [32, 36]	
Sensor neural deafness (common to all MPS types) [19, 32]	Chronic catarrhal otitis → transtympanic drainage (common to all MPS types) [19, 32] *AIEOP-SIMMESN/recommendations MPS I/25.10.2010*
Obstructive sleep apnea (OSA) (common to all MPS types) [32, 38]	OSA → adenotonsillectomy, laser excision of tracheal lesions, and tracheotomy (common to all MPS types) [6, 19, 32] *AIEOP-SIMMESN/recommendations MPS I/25.10.2010*
Restrictive pneumopathy (especially MPSI) *AIEOP-SIMMESN/recommendations MPS I/25.10.2010*	
Systemic arterial blood hypertension Heart failure for mitral aortic valvulopathy Ischemic cardiomyopathy Cardiac conduction abnormalities (BAV III°) (especially MPS I, MPSII, and MPSVI) [27]	mitral-aortic stenosis failure → Valvular reparation/replacement (especially MPS I, MPSII, and MPSIV) [27]
	Abdominal wall hernia(→)hernioplasty (especially MPSI, MPSII) [39, 40]

considered to be "the worst airway management problem a pediatric anesthesiologist could deal with" [21]. Because of this, when possible, general anesthesia should be avoided and, when necessary, administered only by experienced anesthesiologists [18].

4. Management Algorithm (Figure 1)

Standard preoperative preparation for an MPS subject is insufficient and ineffective. A full overview of every single case must be taken for a successful execution of the anesthetic procedure. In fact, the recurrence of deaths related to anesthesia in such patients is increased versus the general population.

In particular, the anesthesiologist must deal with three main concerns in such situations:

(a) difficult intubation,

(b) chronic pulmonary disease,

(c) dangerous neck manipulation for cervical instability [22].

4.1. Preoperative Management

4.1.1. History. Preoperative planning can be considered the most important part of the process. A complete and accurate history of the patient needs to be collected [23], with particular regard to previous anesthetic management, and the time to the present examination, this is to obtain an accurate risk scoring [24]. In fact, a patient who underwent an anesthetic procedure with no complications within one year before the interview can be attributed to a lower risk, since the likelihood of complications is decreased [25].

In cases where more than one year has passed a new evaluation is necessary because the new deposition of GAGs may have altered the previous airway anatomy, the cardiac and pulmonary functions, causing impairments such as Obstructive Sleep Apnoea Syndrome (OSAS).

4.1.2. Objective Examination (OE). Accurate OE includes airway inspection, neurologic, cardiac, ear, nose, and throat (ENT), and visceral assessment.

Table 3: Involvement of organs and systems.

	Clinical manifestations
Upper airways	Facial coarseness, hypertelorism, sunken nasal dorsum, anteverted nostrils, thickened lips, gingival hyperplasia [19] and dental distortions. Swollen tongue, epiglottis, tonsils and adenoids [47], pharyngomalacia (anterior position of larynx [48]).
Lower airways	Expanded larynx and tracheobronchomalacia [49] (enlarged cartilage). Recurrent pneumonia and restrictive lung disease that results in lung failure, Obstructive Sleep Apnea and sudden death for central apnea [5]. Rhinitis, tonsillitis, laryngitis and otitis media [4, 47].
Cardiac	Valvular disease, cardiomyopathy, right ventricular dysfunction and congestive heart failure [2, 27]. Coronary vessel flow impairment and cardiac ischemia [20, 50].
Orthopedic-Bone Changes	Short neck, joints stiffness [47], odontoid instability [48], hypo plastic mandible, thoracic cage restriction for kyphoscoliosis [24]. Hip dysplasia, valgus knee, spinal cord compression and atlanto-axial instability [51, 52].
Others	Mental retardation [14] and hyperactive, aggressive behavior [53]. Communicating hydrocephalus. Hearing loss [2], corneal opacities [54, 55]. Hepatosplenomegaly, umbilical and inguinal hernias [39, 40].

4.1.3. Required Analyses

(i) Laboratory: complete blood count (CBC), arterial blood gas analysis (ABG analysis), serum electrolyte, and liver enzymes.

(ii) Pulmonary function test: vital capacity, functional residual capacity, and total lung capacity (often reduced for skeletal restriction).

(iii) Tracheobronchoscopy and laryngoscopy [26].

(iv) ECG, echocardiography, angiography, cardiac stress test to evaluate valvular structure and functioning, ventricular dimension, and kinetics [27].

The previous study of the airway morphology by imaging is fundamental (Rx, computed tomography (CT), and magnetic resonance imaging (MRI)).

(i) Chest X-ray: pneumonias and atelectasis, often without symptoms, requiring antibiotics and respiratory therapy.

(ii) Cervical spine X-ray (laterolateral): to identify an incomplete anterior ossification of the atlas, a dens dysplasia, and possible dislocations (especially in Morquio and Hurler syndromes).

(iii) Multidetector computerized tomography (MDCT) images [28]: indeed, the preoperative detailed evaluation of the airway morphology is meaningfully useful to influence the anesthetic planning.

Kadic and Driessen [29], in 2012, said that radiological investigation should be performed before the operation and that the problems need to be discussed with the radiologist and the neurosurgeon, in cases of elective surgery. In cases of an emergency, the approach to the airway and the cervical spine should follow the guidelines used for patients with suspected cervical spine injury (rigid collar).

(i) Cervical spine X-ray (flexion): to demonstrate possible tracheal collapse in Morquio syndrome children, a contraindicating condition to head hyperextension during endotracheal intubation.

(ii) Polysomnography: gold-standard investigation for OSAS evaluation [6, 30]. Semenza and Pyeritz retrospectively studied 21 patients and scored an incidence of 50% for OSAS according to clinical history and 90% on the basis of polysomnography [30].

(iii) Somatosensory evoked potentials: to detect early cord compression [5].

(iv) Measurement of CSF pressure if communicating hydrocephalus is suspected [5].

4.1.4. Premedication. Premedication, especially with opioids, enhances the risk of respiratory depression, but is often necessary and used for a better preoperative management of uncooperative children. Furthermore, a certain drug resistance is possible. So particular attention to patients with severe respiratory failure is advisable [20]. Secretions can be reduced with anticholinergic drugs [2, 31].

Antibiotic prophylaxis is a topic of debate; however, in the most recent studies, there is a trend towards avoiding it because it is unnecessary [27].

4.2. Intraoperative Anesthetic Management. Anesthesia should be administered only by an experienced anesthesiologist, who has performed the procedure in the past on this kind of patient, supported by a trained team in emergency situations requiring tracheotomy.

4.2.1. Anesthetic Technique. The choice of the anesthetic technique is another point of interest: general anesthesia is dangerous in MPS subjects, and, when possible, local anesthesia with peripheral blocks should be preferred [25, 41]. On the other hand, the latter is difficult to administer since patients can have mental retardation and present lack of cooperation in many cases, according to the type of surgical procedures required, and thoracic vertebrae dystrophy. To reduce the anesthetic risk, it is a common practice in MPS patients to group together multiple surgical procedures during one anesthetic sitting. Osthaus et al. [42] claimed that to reduce the risks associated with exposure to multiple anesthetics, wherever possible, two or more diagnostic and surgical interventions should be combined during one episode (e.g., MRI and subsequent adenoidectomy).

The choice of technique depends on the anesthesiologist's skill to maintain spontaneous breathing until intubation. Intravenous induction is possible (thiopentone, propofol, midazolam, ketamine) as well as inhalation induction

Table 4: Anesthetic risk: levels and causes.

MPS	Risk level	Multisystem impairment
I H (Hurler) [56] II (Hunter) [57]	Very high High	(i) Tendency to obstruction of the upper airway (ii) Difficult intubation (iii) Presence of thick secretion in the airway (iv) Possible cardiac impairment (v) Possible odontoid hypoplasia
I S (Scheie) [56] I HS (Hurler-Scheie) [56]	Mildly high High	(i) Typical problems of I H (I HS) (ii) Risk of postoperative apnea (iii) Heart disease (in particular aortic insufficiency)
III (Sanfilippo) [58]	Generally not increased	
IV (Morquio) [59] VII (Sly) [50]	Very high	(i) Odontoid hypoplasia (ii) Difficult intubation (iii) Possible alteration of the rib cage (iv) Possible aortic insufficiency
VI (Maroteaux-Lamy) [23]	High	(i) Cardiomyopathy (ii) Severe kyphoscoliosis (iii) Thrombocytopenia (iv) Possible odontoid hypoplasia (v) Delayed awaking

(halothane or sevoflurane) or fiberscope intubation in an awake patient (topical anesthesia) slightly sedated. An important advantage of the fiberscope is the possibility of intubation otherwise impossible, maintaining spontaneous breathing. However, great skill is required especially because of the difficulty to use the nose-tracheal approach (i.e., bleeding). It is also essential to use a small fiberscope diameter (patient size and airway infiltrations).

Inhalation induction and spontaneous breathing maintenance or intravenous induction with fast acquisition of airway control gave positive results in general anesthesia [31]. Kadic and Driessen [29] claim that there is a controversy about the appropriate means of induction. Some anesthesiologists prefer intravenous and others inhalational agents (especially in children). The variability of the anesthetic conduct depends on factors related to the airway morphology, the patient's conditions, the experience of the center, and the type of surgical procedure. The debate about inhalation induction in older patients with established or anticipated airway difficulties rather than intravenous in uncooperative subjects is still open [5].

4.2.2. Induction and Airway Management. Airway abnormalities are a consequence of morphological differences, which often occur in many forms of MPS and imply a predisposition to obstruction and difficult intubation (incidence 25%, failed 8% in Santos et al. [19]), resulting in a possible "cannot intubate/cannot ventilate" scenario [41]. Laryngeal and tracheobronchial cartilage narrowing requires the use of smaller endotracheal tubes than those commonly used [43–45]. In this way, it is also possible to reduce the risk of postoperative subglottic edema [4]. Generally, oral intubation should be preferred due to adenoid and tonsil dimensions, besides nasal mucosa weakness [20]. According to the site and severity of the obstruction, patients may be affected by stridency, dyspnea, cough, and cyanosis [6].

Moreover, during general anesthesia, there is a loss of the muscle tone as a result of decreased cortical influences, chemoreceptor drive, and mechanoreceptor input. There is also a direct inhibition of the airway muscle tone, of the neural activity reflex and of the protective arousal responses. The favorite site of collapse is the velopharynx [46].

Spontaneous breathing is absolutely essential until the achievement of a successful intubation or (at least) until the clear demonstration of the possibility of mask ventilation [25]. Relaxation of the supraglottis tissue may preclude effective mask ventilation, which may be quite difficult (IH, II, and IHS) [25], and also an oral cannula is scarcely helpful [20].

Tracheal intubation should be accomplished during deep inhalation anesthesia without the use of neuromuscular blocking drugs, because the loss of muscle tone may cause the prolapse of the soft supraglottis tissues, acting as a ball valve [41]. However, when necessary, Sam et al. [5] suggest using a short acting nondepolarizing muscle relaxant.

Since intubation is difficult in 50% of cases, blind intubation is advisable; alternatively, it is possible to use a fiber optic flexible bronchoscope [20]; with this device, the anesthesiologist is perfectly aware of the airway anatomy of the patient.

In 1996, Moores et al. [31] reported seven children with MPS1H after stem cell transplantation undergoing 16 anesthetic procedures. Conventional intubation was difficult in 72% and failed in 29%.

Walker et al. [21] published a larger trial, including 13 children with MPS1H without referring to the total number of anesthetics in this group, in which intubation was described as difficult in 54% and failed in 23%.

The largest series of data is available from Mahoney et al. [45] in 1992, analyzing 22 children with MPS1H who received 110 general anesthetics. Difficult airways occurred in 41% of the children or 34% of the conventional intubations. Yeung

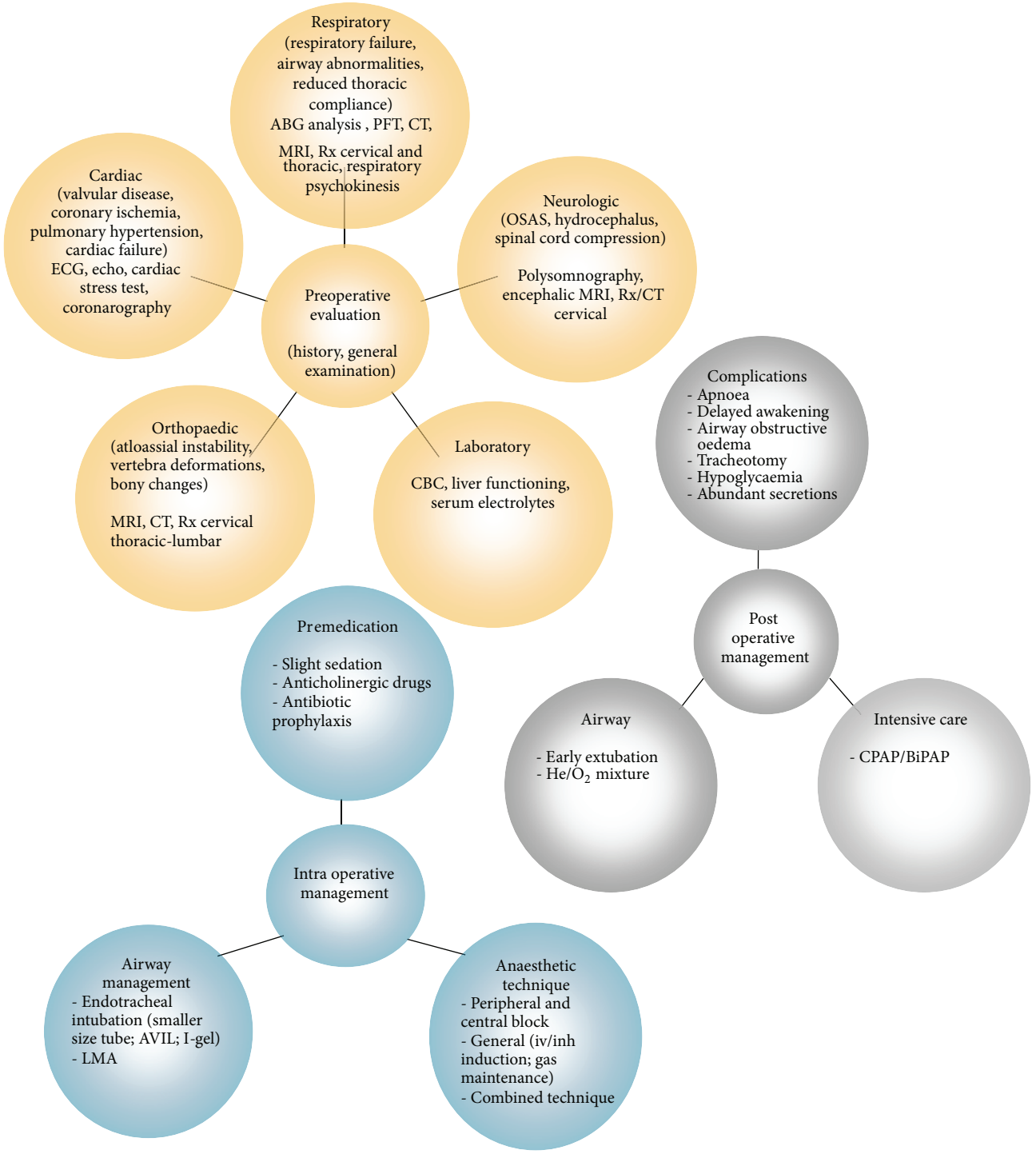

Figure 1: Algorithm of patients with MPS. ABG analysis: arterial blood gas analysis; PFT: pulmonary function test; MRI: magnetic resonance imaging; CT: computed tomography; CBC: complete blood count; ECG: electrocardiogram; Echo: echocardiogram; AVIL: angled video intubation laryngoscope; LMA: laryngeal mask airway; CPAP: continuous positive airway pressure; BiPAP: Bi-level positive airway pressure.

et al. published a retrospective study on 27 patients between 1984 and 2004. 19 (70%) patients had significative upper airway obstruction, diagnosed on the basis of clinical results such as snoring, noisy breathing, OSAS history, desaturation (12 out of 19 patients: 63%), and polysomnography (7 out of 19 patients: 37%). Pulmonary function tests in 15 out of 19 patients revealed reduced FEV1, forced vital capacity, and, of all pulmonary volumes also increased airway resistance was detected.

Direct laryngoscopy evidenced in 5 out of 19 patients macroglossia, oropharyngeal and supraglottis redundant tissue, thickened epiglottis, and reduced tracheal and bronchial

diameter. All 19 patients underwent adenotonsillectomy: 5 (26%) required CPAP before surgery, 3 (11%) urgent tracheotomy [6].

Concordant results, especially regarding obstruction of the airway, can be found in other retrospective studies.

When it is not possible to exclude odontoid dysplasia (IH, II, IHS, IV, VI, and VII), keep a neutral position of the head through cervical collars, premoulded plaster devices [25], or manual stabilization of head and neck (MAIS). In case of malacia, however, the neck extension to maintain tracheal patency could be necessary [20]. To overcome these difficulties, some authors decided to resort to angled video intubation laryngoscope (AVIL); the distal blade has a 25° angle to guarantee a greater visualization [60].

Osthaus et al. [42] identified ten children (three males, seven females) suffering from MPS1H who received 41 elective general anesthetics between 2004 and 2010. They used video laryngoscope successfully on five occasions in four children: once in an urgent situation, once after failed conventional intubation, and three times as the first choice technique.

Laryngeal mask airway (LMA) allows a good airway control without tracheal intubation. This device is used by some authors in MPS patients [21, 61]; in Morquio syndrome and in type I, II, and IV, in fact, the atlanto axial joint is instable, with the impossibility of neck hyperextension [32]. LMA use resolves the problem.

Despite this, there is a high incidence of failure in guaranteeing airway patency through such a device. Busoni and Fognani published a case report to show how LMA caused inspiratory stridency and airway obstruction in an MPS patient (Hunter syndrome) which were solved by mask removal [62]. Therefore, while all the authors agree about the usefulness of LMA in emergency conditions (when ventilation/intubation is not possible) or to make fiberscope intubation easy, there is no agreement about its elective use in MPS patients [25]. Moreover, mechanical complications such as esophageal trauma are possible [63].

Another option is represented by supraglottis devices (I-gel) that allow ventilation and oxygenation during endotracheal intubation attempts [63].

In some cases, direct laryngoscopy was used in children as described by Suh et al. in a case report published in 2010, concerning a 9-month-old boy affected by Maroteaux-Lamy syndrome [64]; airway control was unexpectedly easy, and intraoperative anesthetic management with total intravenous anesthesia went smoothly. In others, it was necessary to use flexible laryngoscope [65], fiber optic video laryngoscope, or intubation through a supraglottis device (LMA and I-gel). We mention some case reports about different anesthetic managements. Yoskovitch et al. [65], in 1998, published a case report about the adenotonsillectomy of a 7-year-old male with Hunter syndrome. The intubation was extremely difficult and performed under flexible laryngoscope guidance. Michalek et al. [63], in a case report published in 2008, described the use of a I-gel supraglottis device in two adult patients with predicted difficult airways and intellectual disability.

The progression of the disease implies a more difficult management in adult patients, with special concerns about the airways, as witnessed in two case reports. Ingrosso et al. [66] published in 2003 a case report about a 41-year-old woman with Sanfilippo syndrome. Subarachnoid anesthesia was chosen and performed with the patient in right-side decubitus and used the laryngeal mask, because of the impossibility to manage the airways.

Nicolson et al. [67] described their experience of an unsuccessful attempt to resolve a failed intubation with fiber optic bronchoscope in an adult patient with Hurler-Scheie syndrome through tracheotomy, ending in the death of the patient.

4.2.3. Maintenance. A proper humidification and heating of the inspiratory mixture is essential, and it is important to avoid hypovolemia to keep tracheobronchial secretions fluid [2], [25].

4.3. Postoperative Management. Complications of awakening after anesthesia are apnea, bronchospasm, cyanosis, and respiratory failure [68], promoted by abundant oral secretions, thoracic cage stiffness, and heart and lung failure, which is why, particularly in IS, IHS, and VI types, intensive therapy is necessary for the following 24–48 hours.

Early extubation, immediately after the procedure, reduces the risk of urgent tracheotomy [24, 69, 70].

Furthermore, regardless of the positive result of surgery, other complications are laryngeal or subglottic edema [4], especially after multiple attempts of intubation, which could make extubation difficult or even impossible.

Certain patients may require reintubation or urgent tracheotomy, because of their incapability to maintain patency after extubation [23].

Postoperative edema is possible until 27 hours after anesthesia [71] with acute respiratory obstruction requiring urgent tracheotomy which could end in the death of the patient. Bredenkamp et al., in 1992, highlighted a significant upper airway obstruction in 17 out of 45 (38%) patients and 7 patients (16%) needed tracheotomy [72]. Ruckenstein et al., in 1991, analyzed 21 MPS patients, 12 of whom required surgery to resolve respiratory obstruction; 3 instead required tracheotomy [73].

Walker et al. [47] described postobstructive pulmonary edema. Inspiratory effort to overcome the obstruction caused a negative transpulmonary pressure gradient with fluid passage from the pulmonary capillaries to the interstitial space. He-O_2 mixture before extubation reduced respiratory effort, reduced obstruction, and improved the outcome, thanks to its lower density compared to air [24, 74, 75].

Other possible complications are postoperative hypoglycemia [20] and exitus [76].

Postoperative treatment includes steroid prophylaxis to reduce edema, standard treatment for patients with upper airway obstruction (biPAP, CPAP [23]), and continuous monitoring of respiratory and cardiac function [68].

5. Conclusions

MPS children are high anesthetic risk patients because of airway narrowing, bone dystrophy, cardiac illness, and

neurological impairment. They require the cooperation of counselors with different professional competences such as otorhinolaryngologists (ORLs), anesthesiologists, and surgeons, under the coordination of a single person—the counselor caring for the child—who keeps the situation for the single patient under control. The best management we can obtain is with the creation of a communicative multidisciplinary team, available to cooperate with other professionals worldwide. The administration of anesthesia should be performed only in specialized centers by experienced anesthesiologists and trained personnel. Indication for surgery should be carried out only after consulting the anesthesiologist, who has the duty to discuss risks and benefits with the parents.

All of this is maimed at improving the quality of life of both patients and families, as can be seen through the use of surveys [77].

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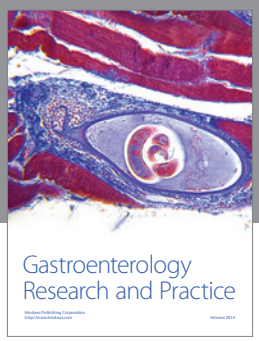

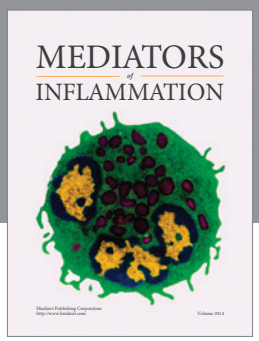

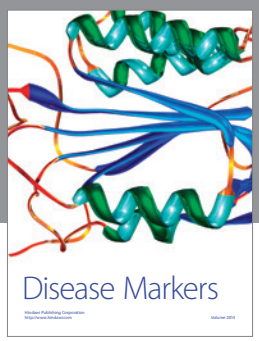

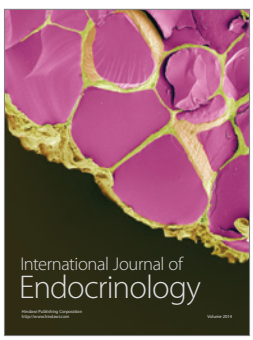

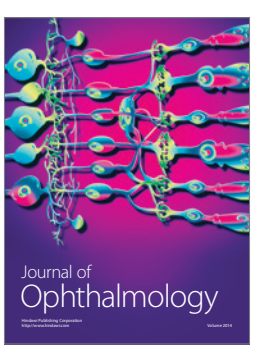

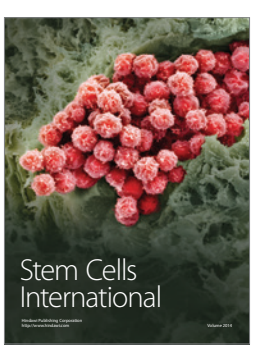

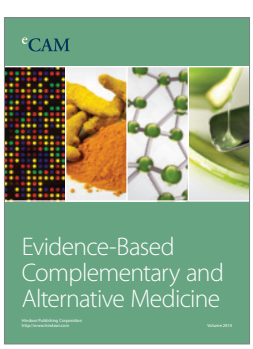

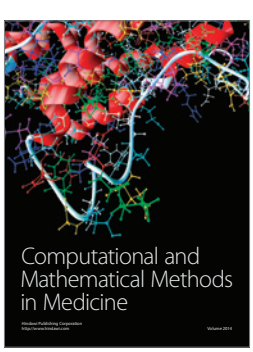

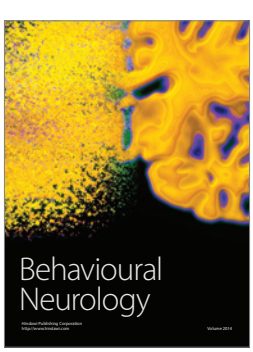

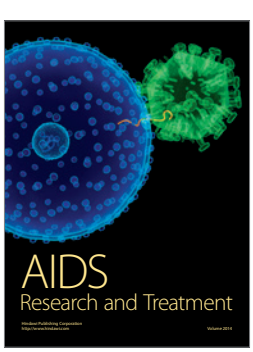

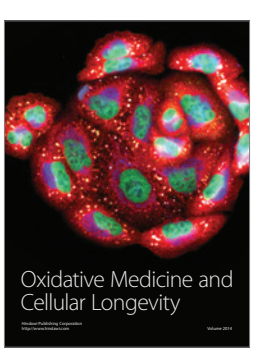

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