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## Decalogue of nebulisation

### Dekalog nebulizacji

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#### Abstract

Aerosol therapy is the basis for the treatment of respiratory diseases. Effective treatment of asthma, infections and inflammations of the upper and lower respiratory tract, and chronic lung diseases is not possible without effective inhalation therapy. Nebulisation is the oldest way of administering medications by inhalation. The clinical effect depends on several elements, without which effective nebulisation cannot be performed. Meeting certain conditions (proper selection of the inhaler, technique of the procedure, dosage) determines the success of the therapy. The article presents the decalogue of nebulisation in a concise manner – a set of basic principles that should be followed by doctors, so that this way of treating respiratory diseases is effective.

#### Decalogue of nebulisation:

1. Nebulisation is a highly effective method of local treatment of the respiratory tract.
2. Effective nebulisation is determined by four elements: proper selection of the inhaler together with the technique of performance, patient respiratory cycle, degree of drug deposition in the lungs, and dosage.
3. Respiratory cycle is an important element of effective nebulisation, which must be taken into account when dosing, especially in children.
4. The selection of nebuliser and technique of performing the procedure are the key conditions of effectiveness.
5. Attention should be paid to the parameters which are important when selecting a proper nebuliser.
6. The deposition in the lungs is determined by the size of the particle and the force of inspiration.
7. The nominal dose is not the deposited dose.
8. Nebulisation time should be short (up to 10 minutes in adults and up to 3 minutes in children).
9. Use the lowest effective (!) dose of the medication.
10. Calculators and applications are helpful in calculating the dose and time of nebulisation.

**Keywords:** nebulisation, inhalers, children, deposited dose of the medication

#### Streszczenie

Aerozoloterapia to podstawa leczenia chorób układu oddechowego. Skuteczne leczenie astmy, infekcji oraz zapaleń górnych i dolnych dróg oddechowych, przewlekłych chorób płuc nie jest możliwe bez skutecznej terapii inhalacyjnej. Nebulizacja to najstarszy sposób podawania leków drogą wziewną. Efekt kliniczny zależy od kilku elementów, bez których nie można wykonać skutecznej nebulizacji. Spełnienie pewnych warunków (odpowiedni dobór inhalatora, technika wykonania zabiegu, dawkowanie) determinuje powodzenie terapii. W artykule w zwięzły sposób przedstawiono dekalog nebulizacji – zbiór podstawowych zasad, jakimi powinni kierować się lekarze, by ten sposób leczenia chorób dróg oddechowych był skuteczny.

#### Dekalog nebulizacji:

1. Nebulizacja to wysoce skuteczna metoda leczenia miejscowego dróg oddechowych.
2. Na skuteczną nebulizację wpływają cztery elementy: odpowiedni dobór inhalatora wraz z techniką wykonania, cykl oddechowy pacjenta, stopień depozycji leku w płucach i dawkowanie.
3. Cykl oddechowy jest ważnym elementem skutecznej nebulizacji, który trzeba brać pod uwagę przy dawkowaniu, zwłaszcza u dzieci.
4. Dobór nebulizatora i technika wykonania zabiegu to kluczowe warunki skuteczności.
5. Należy zwrócić uwagę na parametry istotne przy wyborze odpowiedniego nebulizatora.
6. Wielkość cząsteczki i siła wdechu warunkują depozycję w płucach.
7. Dawka nominalna to nie jest dawka zdeponowana.
8. Czas nebulizacji powinien być krótki (do 10 minut u dorosłych i 3 minut u dzieci).
9. Należy stosować najmniejszą skuteczną (!) dawkę leku.
10. W wyliczaniu dawki i czasu nebulizacji pomocne są kalkulatory i aplikacje.

**Słowa kluczowe:** nebulizacja, inhalatory, dzieci, zdeponowana dawka leku

## 1. NEBULISATION – A HIGHLY EFFECTIVE METHOD FOR LOCAL TREATMENT OF RESPIRATORY DISEASES

The effectiveness of nebulisation treatment results from several advantages listed below:

- direct action at the site of the ongoing disease process;
- the possibility of reducing the dose of the drug, which is connected with the reduction in the number of side effects;
- quick onset of action and the possibility of using this method in emergency situations;
- respiratory tract humidification – each nebulisation procedure is always one of the elements of respiratory system rehabilitation; humidification greatly improves the effects of treatment and distinguishes nebulisation from other inhalation forms;
- acceleration of the mucociliary transport, which facilitates the evacuation of secretions and increases the effectiveness of action<sup>(1)</sup>.

The main advantage of the inhalation therapy over other forms of treatment of respiratory diseases is the possibility of obtaining very high concentrations of the administered drug at the site of the ongoing disease process with simultaneous very small systemic actions of a given drug<sup>(2)</sup>. Introduction of nebulisation reduced the frequency of hospitalisation due to exacerbations of asthma/chronic obstructive pulmonary disease in the elderly<sup>(3)</sup>.

## 2. FOUR ELEMENTS WHICH DETERMINE EFFECTIVE NEBULISATION

Nebulisation is ordered when it is assumed to be effective. The elements influencing clinical effectiveness include:

- proper selection of the inhaler together with the technique of performance;
- patient's respiratory cycle;
- degree of deposition of the medication in the lungs;
- dose of the medication.

## 3. RESPIRATORY CYCLE – ONE OF THE IMPORTANT ELEMENTS OF EFFECTIVE NEBULISATION

The respiratory cycle is one of the main elements affecting the deposition of the medication in the lower respiratory tract. This is due to the fact that deposition of the medication during inhalation occurs only during inspiration. It can be stated that the exhalation is lost for the deposition (and thus – for inhalation). In addition, if the child is crying, the drug is deposited mainly in the upper respiratory tract and stomach, and the lung deposition oscillates around 1%. In this situation, inhalation is ineffective. The respiratory cycle in children differs according to age. The younger the child, the more this cycle is disadvantageous when reaching the lower respiratory tract is concerned<sup>(4,5)</sup>.

## 4. SELECTION OF NEBULISER AND TECHNIQUE OF PERFORMING THE TREATMENT AS THE KEY CONDITIONS OF EFFECTIVENESS

Each patient should have a suitable nebuliser of the right type and with specific parameters.

Currently, the following types of inhalers are available:

- Pneumatic nebulisers: of continuous work, breath-assisting, activated with inspiration, dosimetric. They are used most commonly; they allow the administration of all types of drugs for nebulisation.
- Ultrasonic nebulisers. They are more effective than the pneumatic ones, but the high-energy effect of disrupting liquids by ultrasounds caused by these devices damages the structure of the medication particles.
- Mesh nebulisers. They form a monodisperse aerosol; they are characterised by a short time of nebulisation and low dead volume. They are highly efficient and effective. Due to the small size, they may be used easily on a daily basis<sup>(2,6)</sup>.

The deposition of the drug in the lungs, and also the effectiveness of treatment, depends on the technique of performing the procedure (especially in children). The correct technique of the procedure consists of:

- preparing the nebuliser for work (proper maintenance, washing, putting it together – in accordance with the manufacturer's instructions);
- preparation of the patient (e.g. instructing them about the correct performance of the nebulisation, describing the performed activities to a child etc.);
- correct selection of the nebuliser (see p. 5);
- the right choice of a mouthpiece or a mask (depending on the age of the child – the age of about 3 years is suitable for attempting to change the mask to the mouthpiece, or the patient's condition – unconscious) and correct positioning of the mask (it must closely adhere to the face);
- the patient should breathe calmly, slowly and deeply (after breathing in, adults may hold their breath for a few seconds);
- nebulisation should be short (maximum 10 minutes), especially for children – not longer than 3 minutes.

## 5. IMPORTANT PARAMETERS WHEN SELECTING A PROPER NEBULISER

The most important features of the nebuliser, which ought to be paid attention to, are:

- aerosol volume (air flow through the nebuliser in liters per minute – l/min) – adjust the amount of generated aerosol to the tidal volume of the patient; children under 5 years of age should use a compressor with an air flow (AO) of 4 L/min, older children – 8 L/min, adults – 10–12 L/min;
- consumption of the solution (amount of drug taken through the nebuliser – in mL/min);
- size of the drug particle – pneumatic nebulisers generate aerosols of various particle sizes, so it is important that the cloud contains as many as possible of the ones up to

- 4  $\mu\text{m}$  (fine-particle fraction, respirable), then the pulmonary deposition will be the largest; with larger particles (e.g. 5–8  $\mu\text{m}$ ), the best deposition is in the upper respiratory tract;
- sound level of the nebuliser (the quieter, the better – it distracts and stresses the child less);
  - certificates (each nebuliser should have them), nebuliser chamber (its capacity and dead/residual space is 1 millilitre – mL on average).

## 6. DEPOSITION IN THE LUNGS IS DETERMINED BY THE SIZE OF THE PARTICLE AND THE FORCE OF INHALATION

Deposition of the medication in the lungs is conditioned by:

- size and mass of the dispersed particles (small particles are deposited more peripherally, optimal deposition in the lower respiratory tract occurs at a particle size of 1–3  $\mu\text{m}$ );
- length and speed of inspiration of the patient (long and slow inspiration means better deposition). Slowing down the inspiratory flow of air promotes the deposition of particles.

## 7. THE NOMINAL DOSE IS NOT THE DEPOSITED DOSE (FIG. 1)<sup>(2)</sup>

The nominal dose is the weight of the medication declared by the manufacturer (in an ampoule) and poured into the nebuliser. It can also be a mass of substance planned for use during inhalation.

The emitted dose is the total (upper limit of emission possibilities) mass of the liquid emitted from the nebuliser during one nebulisation.

The delivered (inhaled) dose is a dose that reaches the respiratory tract regardless of the place of deposition. This is of particular importance for continuous nebulisers (the aerosol is emitted at all times), as the delivery of the drug is only possible in an inhale.

The deposited dose (approximately 20–30% of the nominal dose) is the mass of the medication that has been deposited

(“stopped”) in the respiratory tract. This is the actual healing dose.

Nominal dose  $\neq$  emitted dose  $\neq$  delivered dose  
 $\neq$  deposited dose

The volume of the deposited dose is influenced by the nominal dose, the size and mass of the drug particles, inhalation technique, the patient’s age (the younger the patient, the smaller the deposition), the breathing path, the inhaler’s features.

## 8. NEBULISATION TIME SHOULD BE SHORT (UP TO 10 MINUTES IN ADULTS AND UP TO 3 MINUTES IN CHILDREN)

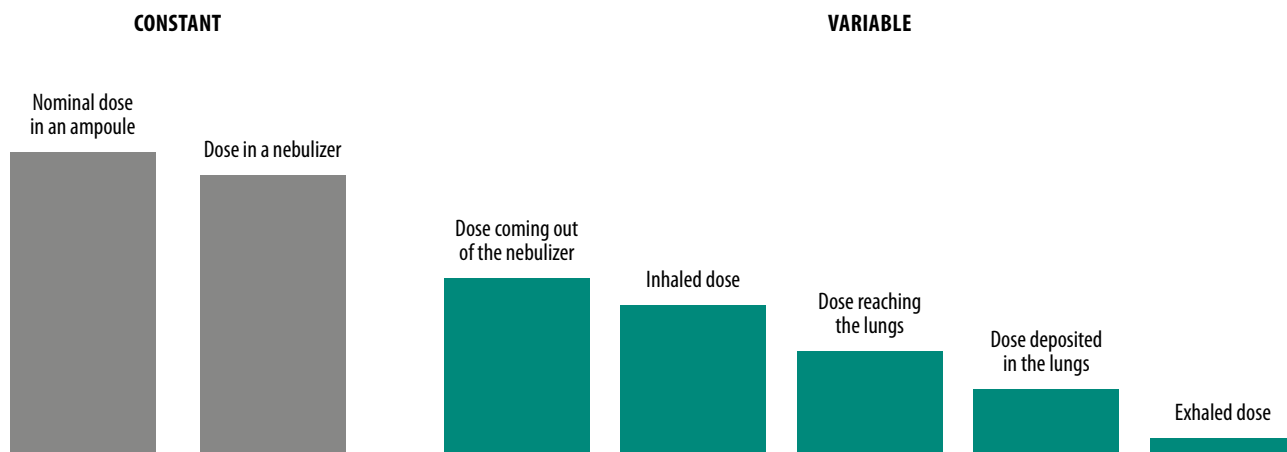
The time of nebulisation affects its clinical effectiveness – the longer it is, the worse the cooperation of the patient, especially of the child. It is assumed that nebulisation should not last longer than 10 minutes, although the author’s experience shows that in children the optimal time is 3–5 minutes (therefore, they should be administered higher drug concentrations, e.g. 500  $\mu\text{g}/1\text{ mL}$ ).

There are four parameters which determine the time of nebulisation:

- drug concentration – reduction by  $\frac{1}{2}$  extends the time twice;
- solution volume – the larger it is, the longer the time;
- nebuliser’s output – the lower it is, the longer the time;
- dilution of the solution – it extends the time of operation<sup>(7)</sup>.

## 9. IT IS RECOMMENDED TO USE THE LOWEST EFFECTIVE (!) DOSE OF THE MEDICATION

The drug is effective when it reaches the right concentration in the target organ (it is deposited in the respiratory tract). It should be remembered that the nominal dose is



118 Fig. 1. Dosages in nebulisation. Regardless of the inhaler, only a small portion of the nominal dose exerts a therapeutic effect<sup>(2)</sup>

Inhaled glucocorticosteroid	Total daily dose ( $\mu\text{g}$ )		
	Small	Medium	Large
Beclomethasone dipropionate (CFC)	200–500	>500–1,000	>1,000
Beclomethasone dipropionate (HFA)	100–200	>200–400	>400
Budesonide (DPI)	200–400	>400–800	>800
Budesonide (nebulisation)	250–500	>500–1,000	>1,000
Ciclesonide (HFA)	80–160	>160–320	>320
Fluticasone furoate (DPI)	100	n.a.	200
Fluticasone propionate (DPI or HFA)	100–250	>250–500	>500
Mometasone furoate	110–220	>220–440	>440

**CFC** – chlorofluorocarbon; **HFA** – hydrofluoroalkane propellant; **DPI** – dry powder inhaler; **n.a.** – not applicable.

Tab. 1. Daily doses of inhaled drugs in patients over 12 years of age according to GINA

not equal to the emitted dose, which is delivered to the respiratory system and finally deposited (1–18% of the nominal dose of the medication).

Currently, it is recommended to use the lowest effective dose. Guidelines and standards (Global Initiative for Asthma, GINA) may come in handy. Tab. 1 presents the proposed ranges of small, medium and large doses in children over 12 years of age and adults. It should be emphasised that in the characteristics of medicinal products for nebulisation there are no precise doses – neither minimal nor maximal ones. In fact, the right dose depends on the patient's condition, the medication, the inhaler and the physician's experience.

In children under the age of 5, a low dose of glucocorticosteroids used in nebulisation is defined as 500  $\mu\text{g}/\text{day}$ <sup>(7,8)</sup>. It seems that in the case of exacerbations and acute obstructive diseases, large and medium doses should be used, and in acute laryngitis – a dose of up to 4,000  $\mu\text{g}/\text{day}$ .

## 10. CALCULATORS AND APPLICATIONS WHICH HELP IN CALCULATING THE DOSE AND TIME OF NEBULISATION

According to Pirożyński, four stages are important when calculating the delivered dose and the deposited one:

- stage 1 – determination of the nominal dose planned for nebulisation (volume and concentration of the drug) in accordance with standards for the treatment of pulmonary diseases and characterisation of the medicinal product;

- stage 2 – clarifying the equipment parameters and determining the dose that can be emitted; it is necessary to know the nebuliser parameter (dead volume – remaining in the nebuliser after inhalation);
- stage 3 – taking into account the frequency of respiration, the breathing pattern and the respiratory cycle (in children it is extremely difficult), and defining the tidal volume;
- stage 4 – calculating the deposited dose (the actual healing dose)<sup>(1)</sup>.

In everyday practice, calculating the deposited dose can be difficult and time-consuming, so it is worth using calculators and applications that quickly convert the most important parameters and data (of the nebuliser and the patient) and calculate the dose and time of nebulisation.

### Conflict of interest

The author does not report any financial or personal connections with other people or organisations that could adversely affect the content of the publication and claim the right to this publication.

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