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Selecting and using nebuliser equipment

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Aim of nebuliser therapy

The aim of nebuliser therapy is to deliver a therapeutic dose of the desired drug in the form of an aerosol of respirable particles within a fairly short period of time, usually 5–15 minutes. To achieve this, nebuliser systems should be expected to provide a drug output with about 50% of the particles below 5.0 μm mass median diameter. It is important to obtain an acceptable range of aerosol particle sizes because of the way in which these are deposited in the tracheobronchial tree.[1–5]

Practical definitions

Jet nebuliser: a nebulising chamber where an aerosol is generated from a flow of gas from an electrical compressor or from a compressed gas supply (air or oxygen). The gas passes through a very small hole (the jet or Venturi) resulting in liquid being sucked up through the small hole from the chamber base and atomised. The resultant large particles then impact upon baffles to generate small respirable particles.[6]

Ultrasonic nebuliser: an electrically driven system whereby a rapidly vibrating piezoelectric crystal vibrates the drug solution and produces aerosol particles of a respirable size.[6]

Flow rate through the nebuliser: the flow rate of gas, whether from a compressed source or from a compressor, that actually drives the nebuliser chamber. It is not the same as the flow rate from the compressor which will often be considerably higher.[7] It is obtained by producing a pressure-flow rate curve for the nebuliser. Recordings of circuit pressure are made from zero flow (maximum pressure) to maximum flow (minimum pressure) using a rotameter, a compressor unit (or flow generator), and pressure measuring device. By substituting the nebuliser chamber for the rotameter the pressure in the circuit can be obtained with a constant flow rate from the flow generator. From the pressure-flow curve the flow rate at the nebuliser can be obtained.[7]

Volume output from the nebuliser: the volume of solution leaving the nebuliser chamber. Whilst useful as a general guide to nebuliser performance, it does not give precise information about the actual drug output.[2]

Drug output from the nebuliser: the actual amount of drug that is released during nebulisation. Because of a variety of factors, including evaporation, a precise measure of drug output (as opposed to volume output) must be assessed using marker techniques.[8]

Residual volume: the volume of solution left in a nebuliser chamber once nebulisation has ceased and all of the aerosol particles have been generated and have left the nebuliser chamber. It is an important volume to take into account when determining the fill volume required to deliver a drug to a patient.[9]

Fill volume: the volume of drug solution initially put into the nebuliser chamber. It must exceed the residual volume by a sufficient amount to provide therapeutic benefit to the patient.[9] It is suggested that it should be at least twice the residual volume. It is important to be aware of the desirable fill volume when prescribing nebuliser drugs in prepackaged ampoules.

The definitions of aerosol output, respirable particles, mass median diameter (MMD), mass median aerodynamic diameter (MMAD), respirable output, and respirable fraction are given in the paper by O'Callaghan and Barry on page S35.

Factors affecting nebuliser performance

The general term "nebuliser" usually implies the combination of the nebuliser chamber and the compressor. Jet nebulisers usually have a constant output, but to prevent wastage new breath-enhanced nebulisers are available where the output is enhanced in the inhalation phase. Ultrasonic nebulisers are effective but are less robust and more expensive than jet nebuliser systems and are generally not used for regular domiciliary therapy.

The major use of nebuliser systems is to deliver bronchodilator therapy. The specification of the nebuliser chamber for administering bronchodilators is different from that required to deliver other drugs such as antibiotics or pentamidine.

The output of a nebuliser is determined by a combination of factors which must be taken into account, and will depend on (1) the design of the nebuliser chamber,[6] (2) the flow of the driving gas and the performance characteristics of the compressor,[7 10 11] (3) the volume of solution (fill volume) of the drug at the start of nebulisation,[9 12] (4) the time taken to nebulise the solution of drug,[7 9] (5) the viscosity, surface tension, and concentration of the drug solution,[13] (6) the residual volume,[9] and (7) tapping of the nebuliser chamber during nebulisation.

The volume output and particle size of water, saline, salbutamol, terbutaline, and ipratropium bromide are similar.[14] For more viscous solutions the volume output is much slower (fig 1).[13 15] The output of steroids may be similar to salbutamol although the drug is a suspension. However, the volume output from a nebuliser is not directly related to the drug output,[8] and the drug output and its availability are different between bronchodilators, antibiotics, and steroids. Measuring volume output is simple and provides a guide to the performance of nebuliser/compressor combinations.[7 16]

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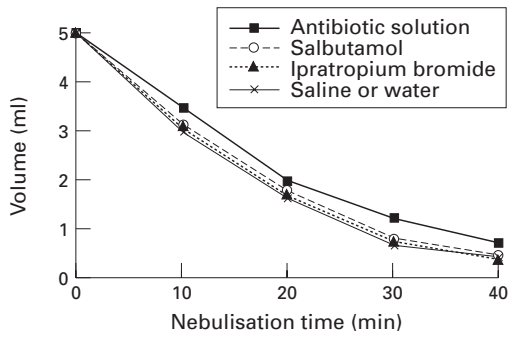

Figure 1 The output of water/saline, salbutamol, ipratropium bromide, and an antibiotic solution. Those solutions with a specific gravity of 1 have similar rates of output. The slightly more viscous antibiotic solution has a slightly slower rate of output. Data from reference 14.

Selecting nebulisers and compressors

The choice of nebuliser and compressor depends on various factors including cost, ease of use and of maintenance, and overall performance. There are many nebuliser chambers and compressors available. Choice should be based on assessment of the systems and comments from other users. It is not advisable simply to pick a nebuliser chamber and a compressor at random. As will be discussed below, the matching of a nebuliser and compressor is important to achieve optimal performance. Furthermore, under certain circumstances particular types of nebuliser or combinations of nebuliser and compressor will be required. The final choice of equipment should be made by the staff of the local unit and not by supplies departments acting in isolation.

Specific information will be required to assist the choice. For the nebuliser this should include data on the flow rate at the nebuliser, residual volume, maximum fill volume, the volume (or drug) output at five and 10 minutes, the MMD (or MMAD), and the percentage of particles under 5 μm. For the compressor the size, weight, noise levels, and ease of use are important considerations for patients and their families. Any clinical data that the supplier can provide on the clinical use of the system should also be obtained.

Nebuliser/compressor combinations

The performance of a given nebuliser chamber is closely linked to the flow of the driving gas and, hence, the performance of the compressor chosen to drive the nebuliser chamber.[7] It is therefore important to use a combination of nebuliser chamber and compressor that delivers an acceptable volume output of drug, with an acceptable range of respirable particles, over an acceptable period of time to the patient.[7 12 16–23]

Table 1 Examples of combinations of compressors and nebuliser chambers supplied for bronchodilator therapy. The compressors have been divided into high, medium, and low flow rates and have been used with the nebuliser chambers indicated

Flow rate	*Compressor*	*Nebuliser chambers sold with compressor unit*	*Multivolt?*
High flow rate (>6.0 l/min)	AFP Classic	MicroMist	No
	AFP Aquillon	MicroMist	No
	AFP Ultima	MicroMist	Rechargeable battery
	AFP Tourer	MicroMist	Yes
	Flaem Nuova Combineb	Flaem Nuova Type 3	Yes
	Flaem Nuova Micelfluss Pro	Flaem Nuova Type 2	Yes
	Medic-Aid CR50	Medic-Aid Sidestream	No
	Medic-Aid CR60*	Medic-Air Ventstream	No
	Medic-Air Freeway		Yes
	Gast*†		?
	Inspiron*	MiniNeb, Incenti-Neb	No
	Medix M Flo	Medix A11	No
	Medix AC2000*	Medix A11	No
	Medix World Traveller	Medix A11	Yes
	Medix Econoneb	Medix A11	No
	Medix Minor*†	Cirrus	No
	Medix Turboneb	Cirrus	No
	Porta-Neb	Medic-Aid Sidestream Medic-Aid Ventstream	No
	Porta-Neb Multi	Medic-Aid Sidestream	Yes
	SunMist Plus	Perma Neb	No
Medium flow rate (4.0–6.0 l/min)	Aeroneb HP†	Cirrus	No
	Atomolette†	Own	No
	Flaem Nuova M70	Flaem Nuova Type 2	No
	NebuPump†	Acorn	No
	Novair II	Cirrus	No
	Pari InhalierBoy†	Own	No
	Pari TurboBoy	Pari LC Plus, LC Plus Junior	No
	Pari JuniorBoy	Pari LC Plus, LC Plus Junior	No
	Pulmo-Aide†	Own	No
	SunMist	Perma Neb	No
	DeVilbiss Traveller	Perma Neb	Yes
Low flow rate (<4.0 l/min)	Aeroneb Standard†	Own, Cirrus	No
	Pari WalkBoy	Pari LC Plus,	Yes
	Aeroneb HP†	Own	No
Others	Aerolyser CF1B†	Wright	Yes
	Aerolyser CF1R†	Respi-Neb	Yes
	Aerolyser 216†	Respi-Neb	Yes
	Flaem Nuova Travelneb	Flaem Nuova Type 3	Yes
	Henley HCU-1†	Hudson MK II	Yes

* Wilson and Steventon have tested these compressors with 19 nebuliser chambers: Acorn, Aerflo, Cirrus, DeVilbiss, Econoneb, Hudson II, Jet set, MicroCirrus, MicroNeb III, MiniNeb, Sandoz, Suremist, Turret Turbo, Unicorn, Unimist, Unineb, Upmist and Wee Neb. With these compressors they all achieved flow rates at the nebuliser of >6.0 l/min.
† These devices may not be currently available but are included since they may still be in use.

Table 2 Details of nebuliser chambers. For each chamber the residual volume, maximum fill volume, the percentage of particles under 5 μm, and the mass median diameter (MMD) is given. The percentage of solution nebulised at five and 10 minutes is also given as a guide to nebuliser output. Data from various sources.

Nebuliser chamber	*Residual volume*	*Maximum fill volume (ml)*	*% nebulised*		*% particles under 5 μm*	*MMD (μm)*
			5 minutes	*10 minutes*		
Acorn	1.76	15	30	38	79	3.69
A11	1.1	?	30	38	58	4.42
Aeroflo	?	?	?	?	?	?
Aeroneb	?	?	19	38	30	7.50
Aeromist	?	?	?	?	?	?
Aiolos	?	?	?	?	?	?
Atomolette	?	?	33	36	28	7.60
Ava Neb 1780	?	?	32	48	58	4.30
Cirrus	0.9	10	40	46	80	3.50
Cloud Chamber	?	10	?	?	42	?
DeVilbiss 646	2.1	3	26	44	70	2.20
Econoneb	?	25	?	?	40	?
Flaem Nuovo Type 2	0.5	7.0	?	?	?	1.32/2.36*
Flaem Nuovo Type 3	0.5	8.0	?	?	?	1.07/4.64*
Hudson Neb MKII	?	?	50	57	82	2.60
Hudson UD I	2.3	17	?	?	82	4.80
Hudson UD II	1.4	10	25	33	79	3.29
Incenti-Neb	?	20	?	?	54	?
Jet set	?	?	?	?	?	?
MicroCirrus†	1.2	10	?	?	90	1.20
MicroMist	?	10	?	?	76	2.10
MicroNeb	0.9	13	28	59	78	3.63
MiniNeb	2.3	38	41	51	79	3.54
Pari Boy	2.0	9	50	64	64	4.16
Pari LC Plus	1.0	8	50	50	60	3.80
Pari LC Plus Junior	0.9	8	55	55	54	4.60
Perma Neb	1.2	9	39	75	70	2.50
Raindrop	?	?	?	?	?	?
Respi-Neb	?	?	?	?	?	?
Respirgard II†	1.3	9	?	?	?	1.88
Sandoz	?	?	?	?	?	?
Medic-Aid Sidestream	0.7	12	?	?	83	3.18
System 22 Mizer	2.0	15	?	?	73	4.65
Turret Turbo	?	20	?	?	73	?
Unicorn 1035	?	10	?	?	68	?
Unineb	?	?	?	?	?	?
Upmist	?	?	?	?	?	?
Venticaire	?	?	?	?	?	?
Medic-Aid Ventstream	1.0	10	?	?	86	3.17
Wee Neb	?	?	?	?	?	?
Wright	?	20	?	?	83	?

The data in this table have been compiled from various sources and provide a guide only. Whilst the residual and maximum fill volumes are accurate, the percentage of solution nebulised at 5 and 10 minutes is the best figure obtainable. This has been obtained for a fill volume of 2–2.5 ml and is generally taken from data obtained with its retail compressor. The % of particles under 5 μm is taken from various sources. Where a ? appears there are no data currently available from any known source.
* Depends on configuration of nebuliser chamber (Type 2) and on type of compressor unit. Data are for diaphragm/rotary piston compressors.
† Data with pentamidine.

BRONCHODILATOR THERAPY

We have divided some currently available nebuliser/compressor combinations into three bands based on the flow rate at the nebuliser (table 1). High flow rate combinations produce more than 50% of the particle size output less than 5 μm diameter and have an MMD of less than 5 μm.[7 16 19–21] The lower flow rate combinations have less than 40% of their particle size output below 5 μm diameter and an MMD of more than 9 μm. The performance of some of the nebuliser chambers is given in table 2. Particle size distributions may differ with different combinations of nebuliser and compressor (fig 2). Breath assisted nebulisers such as the Ventstream and Pari LC have been shown to have improved performance.[23]

An important point about nebulising bronchodilator drugs is whether or not there is a need for a specific combination or combinations. Whilst there are criteria for attaining an optimal performance, this may not matter in practice since subjective benefit and objective bronchodilatation are the most important factors. There are a number of nebuliser/compressor combinations currently available that do not achieve the standard criteria.[7] However, these systems are still being used and there have been no reports to suggest that long term use of a poor performance system has resulted in either a reduction in the quality of life or increase in hospital admissions. Part of the reason for this is probably that the doses of bronchodilator drugs being administered are large and that even inefficient systems deliver enough drug to ensure maximal bronchodilatation.

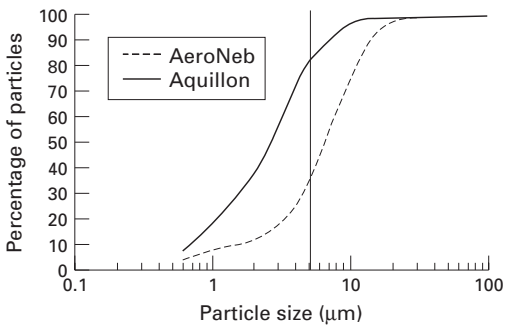

Figure 2 Two examples of particle distribution showing the cumulative percentage of particles within different particle sizes for a high flow rate combination (Aquillon compressor with Neb MK II; flow rate 7 l/min) and a low flow rate combination (AeroNeb Standard compressor with Cirrus; flow rate 3 l/min). The fill volume in both cases was 2.5 ml of sterile water. For the Aquillon the percentage of particles less than 5 μm was 83%, while for the AeroNeb Standard it was 35%. Based on data from reference 7.

Table 3 Examples of nebuliser/compressor combinations for antibiotic therapy

Compressor	*Nebuliser chamber*
Medic-Aid CR60	Respirgard II
Medic-Aid Porta-Neb	Medic-Aid Ventstream
Medic-Aid CR50	Medic-Aid Sidestream, MicroCirrus, Raindrop, Hudson UD II
AFP Tourer, AFP Classic, AFP Aquillon, AFP Ultima	Medic-Aid Ventstream, MicroMist, MicroNeb III, MicroCirrus, Medic-Aid Sidestream
Pari TurboBoy	Pari LC Plus, Pari LC Plus Filter
Pari JuniorBoy	Pari LC Plus Junior, Pari LC Plus Filter

Data from various sources and from other centres using antibiotic therapy. This list is not exhaustive and other devices may be suitable.

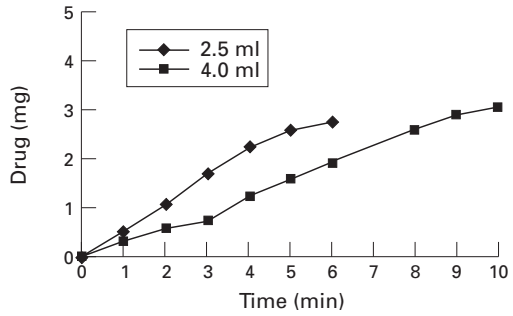

Figure 3 Comparison of rate of delivery of drug with a 2.5 ml and a 4.0 ml fill volume. The 2.5 ml fill volume delivers the same amount of drug as the 4.0 ml fill volume but in approximately half the time. Data obtained using a Sidestream nebuliser under simulated tidal breathing using compressed air to drive the nebuliser. The residual volume is 0.5 ml. For a fill volume of 2.5 ml nebulisation time to "dryness" was six minutes which increased to 10 minutes using the 4 ml fill volume. The 70% increase in nebulisation time increased the drug output by only 12%. Data from reference 12. Reproduced from reference 9 with permission.

ANTIMICROBIAL AGENTS

It is preferable for high power nebuliser systems to be used with antibiotics.[16 24–28] A powerful, continuously rated compressor should be used (table 3). Various nebuliser chambers have been shown to be acceptable, although in some cases nebulisation times were longer than is perhaps ideally required by the patient.[29]

MUCOLYTICS AND SALINE

Where mucolytics such as acetylcysteine are used, standard delivery systems, as shown in table 1, can be used. The high and medium flow rate systems appear to be adequate,[30 31] especially since there appears to be little difference in the rate of output of saline and of bronchodilators.[14]

RHDNASE

Current recommendations are based on limited data.[32–35] rhDNase should be nebulised using a jet nebuliser since ultrasonic nebulisers may inactivate it or have unacceptable aerosol characteristics. Recommended combinations are given in table 4.

STEROIDS

These can be nebulised with medium or high power systems as shown in table 5.

Volume-time output and fill volume

Four criteria should be considered:

(1) The minimum initial fill volume is determined by the size of the residual volume of the nebuliser chamber. The larger the residual volume, the greater the initial fill volume will need to be.[9 17 22] The residual volume of the modern, small volume, nebuliser chambers is less than 1.0 ml (table 2) and for these a fill volume of 2.0–2.5 ml of drug solution is enough. Increasing the fill volume with a small volume nebuliser (Sidestream) will deliver the same amount of drug but over a longer period of time (fig 3).[12] Where the residual volume is greater than 1.0 ml, a larger initial fill volume is required. Since many nebuliser drugs are now available in prepackaged ampoules of 2.0 ml or 2.5 ml, it is important to ensure that the nebuliser chamber used by a patient either has a small residual volume or that the patient is instructed to dilute the contents of the ampoule with normal saline and to make up the initial fill volume to at least twice the size of the residual volume. Table 6 lists suitable combinations of nebuliser chambers and drug ampoules.

(2) The time taken to deliver the drug is important for patient compliance. The optimum time for nebulisation is 5–10 minutes. Patients will generally not accept long delivery times (fig 4), especially if the treatment is required several times per day.[29]

(3) The end point of nebulisation needs to be defined. There is some evidence that nebulising "to dryness" is confusing for patients and is difficult for them to define (fig 5). Jet nebulisers nebulise continuously until the fill volume approaches the residual volume and "spluttering" occurs.[36] At this point, although

Table 4 Recommended nebuliser/compressor combinations for rhDNase therapy

Compressor	*Nebuliser chamber*
Pulmo-Aide	Hudson T Up-draft II
	Airlife Misty
	A11
Pari InhalierBoy	Pari LL, Pari LC
Pari TurboBoy	Pari LC Plus
Aiolos	Aiolos
Medic-Aid Porta-Neb	Medic-Aid Sidestream
Medic-Aid CR50	Medic-Aid Sidestream
Medic-Aid CR60	Medic-Aid Sidestream
AFP Aquillon	MicroMist

Data from studies using Pulmozyme.

Table 5 Examples of nebuliser/compressor combinations suitable for corticosteroid therapy

Compressor	*Nebuliser chamber*
Medic-Aid Porta-Neb	Medic-Aid Ventstream
	Medic-Aid Sidestream
	Cirrus
	Hudson
	Turret
Medic-Aid Freeway	Medic-Aid Ventstream
Medic-Aid CR60/CR50	Cirrus, A11
	DeVilbiss 646
	Hudson Up-draft II
	Turret
AFP Aquillon	MicroMist
AFP Tourer	Medic-Aid Sidestream
AFP Ultima	Medic-Aid Sidestream
Pari TurboBoy	Pari LC Plus, LC Plus Junior
Pari JuniorBoy	Pari LC Plus, LC Plus Junior

Data from various sources. This list is not exhaustive and other devices may be suitable.

Table 6 Nebuliser chambers suitable for use with proprietary pre-packaged nebuliser solutions

Drug	*Trade name*	*Ampoule size (ml)*	*Nebuliser chambers*
Terbutaline	Bricanyl Respules	2.0	Pari LC Plus, LC Plus Junior, Cirrus, Medic-Aid Sidestream, Flaem Nuova Types 2 and 3, MicroNeb, Medic-Aid Ventstream
Ipratropium†	Atrovent	2.0	
	Steri-Neb ipratropium	2.0	
Salbutamol/ipratropium	Combivent	2.5	As 2.0 ml plus Respirgard
Salbutamol	Steri-Neb Salamol	2.5	
	Ventolin Nebules	2.5	
Fenoterol/ipratropium	Duovent	4.0	All of above, plus A11, Hudson, Pari Boy
Budesonide	Pulmicort Respules	2.0	Medic-Aid Ventstream, Cirrus, Turret, Hudson MicroMist, DeVilbiss 646, Pari LC Plus, LC Plus Junior
Sodium cromoglycate	Intal	2.0	As above for 2.0 ml
Dornase alpha	Pulmozyme	2.5	Hudson UD II, Acorn, Medic-Aid Sidestream, Medic-Aid Ventstream, Aiolos, Pari LC Plus

It is taken that at least 50% of the drug solution should be available for nebulisation and without the need for dilution with normal saline. Data from British National Formulary.
† Also available in 1.0 ml ampoules containing 250 µg/ml. The 2.0 ml ampoule contains 500 µg/ml. Use of the 1.0 ml ampoule will need dilution as no nebuliser chamber has a residual volume of less than 0.5 ml.

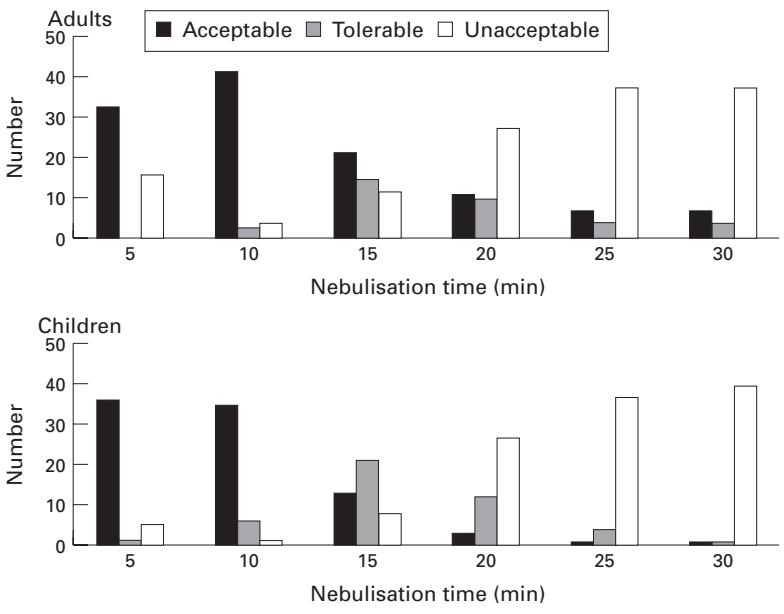

Figure 4 Patient acceptability of different durations of nebuliser treatments. Most patients preferred a treatment time of 10 minutes or less. Unpublished data from R S E Wilson.

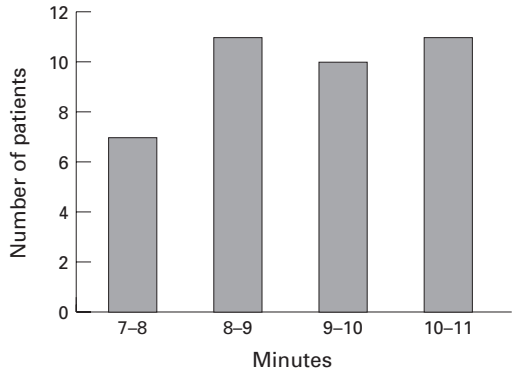

Figure 5 Recognition by patients of "dryness" at the end of nebulisation. The combination of a Charles Austen compressor with a MiniNeb nebuliser would usually reach residual volume in 10 minutes with a fill volume of 2.0–2.5 ml. Following explanation of the meaning of "dryness", patients timed the system to "dryness" with a stopwatch in minutes and seconds (n = 39 episodes). Unpublished data from J Pugh and R S E Wilson.

volume output is reduced because of evaporation, drug output remains high for a short period of time (fig 6). This suggests that patients should be told to nebulise until spluttering occurs and then to continue for a further minute. Previous tests should have shown that, with the fill volume used, the system reaches this point in 10 minutes or less. It is essential that the compressor/nebuliser combination is working efficiently and has no faults.

(4) During nebulisation (particularly with new units) large particles tend to adhere to the sides of the nebuliser. Adherence becomes less as the nebuliser ages. These large particles can be encouraged to fall back into the well of the chamber by tapping the side of the nebuliser chamber once the nebuliser begins to "splutter". There is evidence that this may improve output by up to 50% over a given period of time (fig 7).

Ease of use

The choice of nebuliser chamber should, to some extent, be based on its ease of use. In general, chambers should (1) not contain components that can be easily swallowed by small children (ideally, all nebulisers should consist of a removable top and the single component chamber); (2) be easily disassembled and reassembled by patients of all ages (this is particularly important in the elderly and in patients whose manual dexterity is significantly impaired); and (3) employ a chamber that can be left connected to the compressor, rest on a flat surface, or be mounted on the compressor itself, and so be filled easily.

Mouthpieces/face masks and venting circuits

Lung deposition is the same in adults or older children, when either a mouthpiece or face mask can be used.[37 38] Face masks are better for infants and younger children, and for emergencies. Mouthpieces are recommended when steroids or anticholinergics are being nebulised.

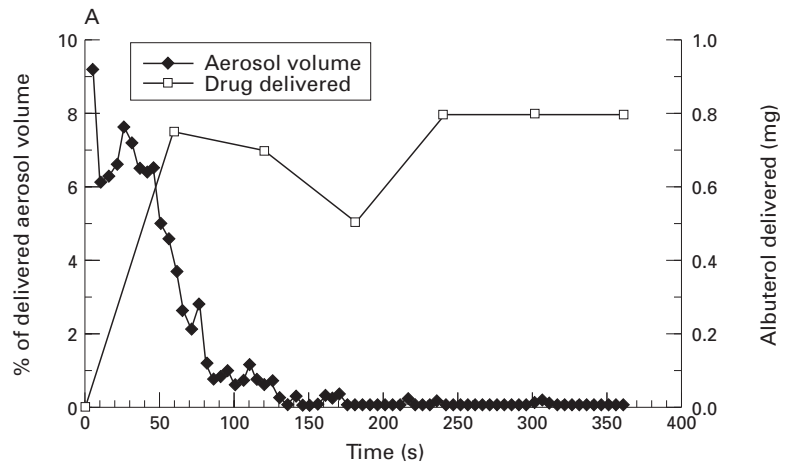

Figure 6 Aerosol output rate (percentage of aerosol delivered every five seconds) and drug output for initial fill volumes of (A) 1.5 ml, (B) 2.5 ml, and (C) 3.5 ml plotted over six minutes of nebulisation. A DeVilbiss 646 jet nebuliser and a Pulmo-Aide 5610D compressor were used. With a fill volume of 1.5 ml there was an abrupt fall in output after 45 seconds whilst with fill volumes of 2.5 ml and 3.5 ml the fall-off points were 160 seconds and 320 seconds, respectively. Each of these abrupt fall-off points corresponded to the onset of nebuliser "spluttering" – the point where the droplet rain-off from the nebuliser walls is insufficient to supply aerosol for renebulisation. There is an audible change in pitch and air bubbles can be seen sporadically. Drug output was observed to decrease at approximately these points with the 1.5 ml and 2.5 ml fill volumes. Redrawn with permission from reference 36.

If a face mask is used it should be closely fitting to the face and should not be held away from the face.

BRONCHODILATORS

Usually the choice depends on patient preference. Use of ipratropium bromide poses potential problems in patients with glaucoma. There have been no long term studies but short term studies in normal subjects and in patients with narrow angle glaucoma show that up to four times the recommended dose of inhaled ipratropium has no effect on intraocular pressure, pupil diameter, or accommodation.[39–41] However, prolonged pupillary dilation occurs if ipratropium is sprayed directly into the eye.[42] The addition of salbutamol intensifies the risk, especially in patients with glaucoma,[43 44] so patients should be carefully instructed in the use of nebulised anticholinergic agents, ensuring that a face mask is tight fitting, or preferably, that administration occurs via a mouthpiece.

ANTIBIOTICS

There are possible risks to staff associated with exposure to antibiotics (see paper by Webb and Dodd on pp S69–71), so it is important that the circuit should contain either a filter or the exhaled air be vented directly to the external atmosphere by wide bore tubing through an open window. Where appropriate filters are available, these should be used in preference to venting. Mouthpieces should be used.

Appropriate antibiotic T-pieces and circuitry is important to prevent waste from the system polluting the surrounding atmosphere, although there is no published medical evidence to indicate that pollution of the hospital atmosphere may lead to the establishment of resistant organisms.

STEROIDS, PENTAMIDINE

Mouthpieces are the preferred option.

Single use or single patient use?

The Medical Devices Agency has recently issued a bulletin[45] regarding the use of devices such as nebulisers for single use or single patient use. Where nebulisers are marked by the manufacturer as "single use" they may only be used once and should then be discarded. Where nebulisers are marked "single patient use" then they are reusable items that are capable of being reused, with or without reprocessing, by an individual patient. Some nebuliser chambers are reusable and so may be used on different patients as long as appropriate reprocessing, as indicated by the manufacturer, is followed.

Whilst nebuliser chambers have been categorised as "single patient use" for many years throughout the world, this new clearly defined categorisation of the use of devices means that both the manufacturer and physician in charge should define the extent and the methods by which "single patient use" devices should be used and reprocessed. Within the letter of the law, devices marked "single use" should only be used once and then discarded. Reusing such devices may leave the physician and/or the respiratory team open to litigation should any problem arise as a result of using a "single use" device as a "single patient use" device. Manufacturers should mark the packaging of

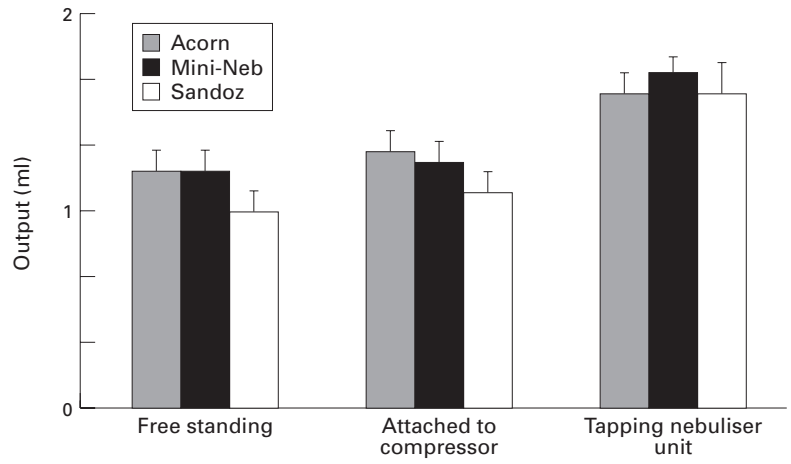

Figure 7 Effects of "tapping" on the volume output from 10 nebuliser units. The in-circuit flow was 6–8 l/min, the fill volume was 2.0 ml, and the nebulisation time was over 10 minutes. Data from reference 14.

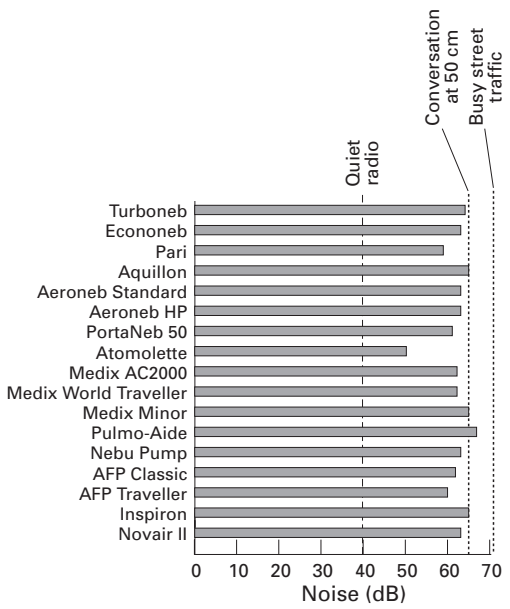

Figure 8 Range of noise encountered when using various nebuliser/compressor systems. Noise was measured one metre from the combination of nebuliser/compressor using standard equipment. Data from reference 7.

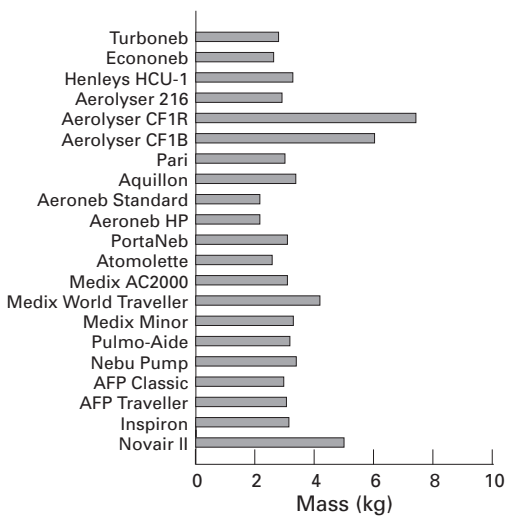

Figure 9 Variation in weight for a number of nebuliser/compressor units. Data from references 7 and 17.

nebuliser chambers as "single use" or "single patient use" and provide instructions for re-processing of "single patient use". The user must ensure that he or she uses the correct type of device and, if in doubt, should contact the supplier directly. Items that contain no indication of use should be avoided.

One major problem with nebuliser chambers is their potential for cross-infection. To date there does not appear to be any evidence that these devices are responsible for the acquisition of infecting organisms, although bacterial cultures of non-pathogenic organisms have been reported.[46 47] It is therefore important that good hygienic practice is followed[48] to reduce, as far as possible, any risk of infecting organisms being colonised within the nebuliser chamber.

Further research into this and into aspects of the degradation of nebuliser performance with time are required to clarify the need for carefully defining how nebuliser chambers are used in practice.

Compressors: other factors for consideration

STANDARDS

All compressors should be certificated to British Standard 5724 or to an European equivalent. The certificate should be from an independent testing authority which should be stated by the manufacturer.

NOISE

Noise can be an important factor in the acceptability of treatment, both to the patients and to their families and friends. The system should be as quiet as possible. An assessment of the noise of a range of devices is depicted in fig 8 which shows the range and how it relates to a variety of defining points used to assess noise pollution.[7]

WEIGHT

To be portable, the compressor and associated components should be as light as possible. This is particularly important to patients who have to travel with their system.[7 16] The weights of various compressor/nebuliser combinations are shown in fig 9.

COSTS

Running costs may be an important consideration for patients with limited income. Low energy consumption units would therefore be appropriate for these patients, so long as the other performance requirements were met. Figure 10 shows the relative costs of various compressors where a patient has four 15 minute nebulisations/day for one year.[7] These costs are calculated from the power rating

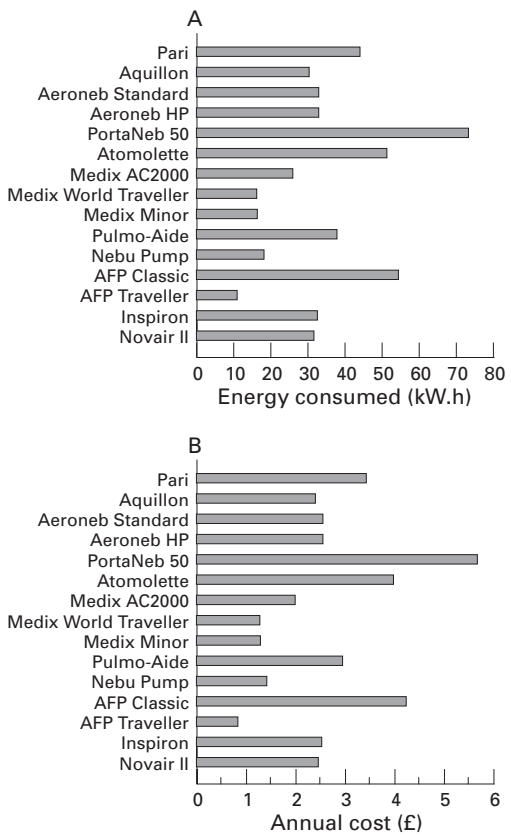

Figure 10 Variation in costs of running a nebuliser/compressor unit for four periods of 15 minutes per day for one year. The data are presented as energy consumed (kW.h), the actual cost being dependent on local electricity charges. Data from reference 7.

(volts × amps = watts) of the compressor and the cost of a unit (1 kW.h) of electricity. Thus, if the compressor is rated at 50 watts a total of 20 hours (1000/50) of usage will equal a single unit of electricity. For four 15 minute nebulisations per day, a unit of electricity will be consumed every 20 days. The cost is therefore 365/20 units multiplied by the cost per unit of electricity. So, if the unit cost is £0.0773, the total electricity costs will be 365 × 0.0773/20 or £1.41 per year.

POWER SUPPLY

In the UK and many other countries the power supply will be 220–240 V and 50 Hz. In most of the Caribbean, Canada, Japan, some Middle Eastern countries, the USA, and some parts of South America the voltage is usually 100/110 V. It is therefore important that devices should be available for the patient using nebulisers who wishes to travel abroad. A few systems are multivolt and can be run at 100/110 V or on a 12 V DC source for use with car batteries. Those systems which are multivolt are indicated in table 1.

Conclusion

From the evidence presented it appears that the nebuliser/compressor should be able to deliver 2.0–2.5 ml of bronchodilator solution at a constant rate, with the particle size such that most are less than 5 μm. For other substances the evidence is less clear.

For the future

The major problem encountered in choosing the appropriate combination of nebuliser and compressor is the scarcity of consistent information. There is clearly a need for the assessment of all possible combinations currently available, and there must also be a clear consensus as to what information is essential and what is helpful but secondary in use.

To provide information on every combination of nebuliser and compressor will be difficult, time consuming, and expensive. However, if a number of laboratories were to be accredited to perform comparisons to set protocols, much of the difficulty in making statements about nebuliser and compressor combinations for the various nebulised drugs would be reduced.

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Appendix: Suppliers of nebulisers and compressors

Aerosol Medical Ltd Wyncolls Road Colchester Essex CO4 4HT, UK	Tel: +44 1206 842244	Wright nebuliser Aerolyser CF1B CF1R, 216
AFP Medical 71 Somers Road Rugby Warwickshire CV22 7DG, UK	Tel: +44 1788 578121 Fax: +44 1788 540199	AFP Classic AFP Tourer AFP Aquillon AFP Ultima Hudson MicroMist
Bard Ltd Pennywell Industrial Estate Sunderland SR4 9EW, UK	Tel: +44 191 534 3131	Incenti-Neb nebuliser Inspiron MiniNeb Inspiron compressor
Carri-Med Ltd Glebelands Centre Vincent Lane Dorking RH4 3YX UK	Tel: +44 1306 886180	Nebupump compressor
DeVilbiss Healthcare Airlinks, Spitfire Way Heston Middlesex TW5 9NR UK	Tel: +44 181 756 1133 Fax: +44 181 573 1769	SunMist SunMist Plus DeVilbiss Traveller Perma Neb
Flaem Nuova Via Colli Storici 73-25010 S Martino Della Battaglia Brescia Italy	Tel: +39 30 9910168 Fax: +39 30 9910287	Type 2 nebuliser Type 3 nebuliser TravelNeb Combineb, M70 Micelfluss Pro
Henleys Medical Supplies Alexandra Works Clarendon Road Hornsey London N8 0DL UK	Tel: +44 181 889 3151	Cloud Chamber nebuliser Hudson UD II nebuliser HCU-1 compressor
Intersurgical Molly Millars Lane Wokingham Berkshire RG11 2RZ UK	Tel: +44 1734 795579 Fax: +44 1734 795555	Cirrus, MicroCirrus Novair compressor
Lifecare Hospital Supplies 28A Scotland Road Market Harborough Leics LE16 8AX UK	Tel: +44 1858 431455	MicroNeb
Medic-Aid Ltd Heath Place Bognor Regis West Sussex PO22 9SL, UK	Tel: +44 1243 267616 Fax: +44 1243 262979	Sidestream Ventstream Porta-Neb CR50, CR60 System 22 Turret nebuliser
Medix Ltd Clement Clarke International Ltd Edinburgh Way Harlow Essex CM20 2TT UK	Tel: +44 1279 414969 Fax: +44 1279 635232	Medix AC2000, World Traveller Medix M Flo Medix A11 Medix TurboNeb
Pari GmbH Moosstrasse 9 D-82319 Starnberg Germany	Tel: +49 8151 279-0 Fax: +49 8151 279-101	Pari LC Plus Pari InhalierBoy
Sinclair Medical Ltd Borough Road Godalming Surrey, GU7 2AB UK	Tel: +44 1928 717070	Atomolette nebuliser/compressor

From the data available the authors have, as far as possible, provided accurate and up to date information on the products listed in this document and apologise for any omissions or inaccuracies contained herein.