Archives of Emergency Medicine, 1992, **9**, 44–50

Efficiency of suction pumps for the emergency medicine setting

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INTRODUCTION

Suction pumps form an important part of the equipment for field treatment of emergency patients (ECRI, 1979; Silverton, 1980; Rossi, 1983; Dick, 1985). Basically, a distinction must be made between devices that are mechanically driven (hand- or pedal-operated) or driven by external energy, i.e. electrically or pneumatically. The advantage of the latter is that they are not depending on any exhaustible power sources (batteries, gas cylinders). Their shortcoming is that the energy needed is often considerable, and the operation (e.g. in difficult external conditions) often requires a second helper. It is possible to lay down a number of basic demands (Ahnefeld *et al.*, 1979; Thiemens, 1980; Schäffer *et al.*, 1982; Rossi *et al.*, 1988) to be fulfilled to assure suitability for practical use (Table 1).

MATERIALS

The following mechanically driven suction pumps were tested:
- Ambu Minipump (Ambu International A/S, Copenhagen, Denmark)
- Ambu Twin pump (Ambu International A/S, Copenhagen, Denmark)
- Ambu Uni-Suction pump (Ambu International, Copenhagen, Denmark)
- Söhngen pedal-operated suction pump (Söhngen, Wehen, Germany)
- Vitalograph Aspirator (Vitalograph, Hamburg, Germany)
- Weinmann Manuvac (Weinmann, Hamburg, Germany)

Based upon the technical design features the devices may be devided into different groups. The Ambu Minipump and the Söhngen pedal-operated pump are based upon similar design principles (springloaded pumps). The Weinmann

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Table 1. Requirements of suction pumps.

Requirements of suction pumps
Small dimensions (to be accommodated in an emergency case)
Low weight
Stability (against physical impact and chemical influence)
Sufficient suction chamber capacity
Large bore tubes
Ready for use without any preparations
Reliability, also under adverse conditions
Sufficient performance (vacuum, maximum flow)
Simple setting-up/taking down
Hygienic cleaning/disinfection
Moderate price

Manuvac and the Ambu Uni-Suction pumps are membrane pumps. The Vitalograph hand pump is based upon a gun-like concept. The Ambu Twin pump consists of two reciprocating pistons.

METHODS

Firstly the pumps were investigated concerning their technical specifications like dimensions, weight, volume capacity of the pistons, tube diameter and length (Table 2). The measurements of the power needed for suctioning air and various fluids were done with calibrated spring-scales. Vacuums, flows, volumes and suction capacities were measured by Fleisch-Pneumotachograph (Pulmostar: Dr. Fenyes & Gut, Basel, Switzerland). Piston displacement by one single pump action was evaluated for air and water. Resulting airflow was determined while performing two aspirations per second at the maximum working speed. An evaluation of the suction capacity to determine the time needed to aspirate 250 ml of water or salad oil, which represented a viscous fluid, was carried out. The testing arrangement was such that both pump and test fluid were on the same level to assure that no continuous suction effect might be generated.

RESULTS

To evaluate the performance of the pumps the measuring shown in Table 3 was carried out.

The power needed for suctioning air varied between 10 and 400 N (approximately 1–40 kp). The aspiration of water required 15–400 N and was especially dependent

Table 2. Technical specifications.

Device	Ambu minipump	Ambu twin pump	Ambu uni-suction	Söhngen pedal suction pump	Vitalograph aspirator	Weinmann manuvac
Manufacturer/ distributor	Ambu International A/S Sdr. Ringvej 49 – P.O. Box 215 DK-2600 Glostrue – Copenhagen, Denmark			Söhngen GmbH D-6204 Taunusstein, Wehen, Germany	Vitalograph LTD. Deutschland D-2000, Hamburg 11, Germany	Weinmann GmbH & Co., D-2000 Hamburg 54, Germany
Dimensions (cm) Incl. tubing	22 × 10 × 18	23·6 × 12·6 × 10·3	26 × 18 × 13	18 × 9·6 × 16·5	16·5 × 16·5 × 8·7	20·5 × 17.5 × 10·6
Weight (kg)	1·0	1·1	2·1	0·8	0·4	1·4
Volume-capacity (ml)	300	750	650	300	230	370
Tubing diameter (mm)	6	10	8	6	*	6 or 10
Tube length (cm)	150	140	140	120	*	28 + 80

* Depending on tube used

Table 3. Readings.

Device	Ambu minipump	Ambu twin pump	Ambu uni-suction	Söhngen pedal suction pump	Vitalograph aspirator	Weinmann manuvac
Power used (air) (*n*)	400	30	30	430	15	10
Power used water (*n*)	400	80†/40‡	130†/40‡	430	25‡/15¶	100**/306††
Vaccum-max (bar)	0·5	0·8	0·6	0·5	0·6	0·7
Piston displacement (ml water)	190	265*	150	250	30	160
Piston displacement (ml air)	240	300*	205	270	35	200
Flow at 2 Hz ($l\,min^{-1}$)	19·3	33·4	20·7	18·1	4·5	17·1
Flow = max. ($l\,min^{-1}$)	23·4	67·4	37·0	24·3	7·0	22·8
Suction capacity (s 250 ml^{-1} water)	6	2·5†/1‡	4·0†/2·0‡R	9	8§/3§	63**/1·5††
Suction capacity (s 250 ml^{-1} salad oil)	17	2·5†/2·3‡	2·0†/1·0‡	25	27‡/12¶	17**/2††

* Due to the design principle two cycles were run for each suction cycle

¶*† with catheter tip with endotracheal tube ‡ without catheter tip ** with thin tubing § without catheter tip †† with thick tubing

on the type of tube used. The maximum vacuum was between 0·5 and 0·8 bar. With a single aspiration volumes of 30–300 ml could be suctioned. The maximum flows were measured between 7 and 67·4 $l\,min^{-1}$. The suction capacity for water and viscous fluids depended mainly on the tube used, varying between 1 and 27 s for aspirating 250 ml.

DISCUSSION

As regards dimensions and weight the Ambu Uni-Suction was outside the range as its dimensions make it special. The other pumps have dimensions and weights which make them easier to transport and accommodate in an emergency case (Ahnefeld *et al.*, 1979; Thiemens, 1980).

There was also a great difference between the capacitive volume of the suction chamber. However, according to our practical experience, a capacity of 200–300 ml

is probably more than adequate in the majority of emergency situations, which is contradictory to the testing criteria of other researchers (ECRI, 1979; Dick, 1985). A mechanically-driven pump designed for extraclinical emergency care does not need the same volume as those used in emergency wards, operating theatres or intensive care units where for example complete evacuation of the stomach contents may be necessary (Schäffer, 1982; Rossi, 1983).

On the other hand, the design should allow quick emptying of full containers in the event the capacity should actually be fully utilized. A device which has been prepared for 'continuous' outpouring of excess suction chamber contents offers additional advantages in this respect (Ambu Twin pump). On the whole, usefulness in practice can be confirmed for all the devices as regards the size of the suction chamber.

In principle the suction tubing should be transparent to enable continuous checking of the suction process and assessment of the aspirate. All the current versions of the devices fulfil this requirement, while some of the older versions have black rubber hoses.

For the suction of low viscous secretion and/or blood thin lumina may suffice. However, vomit cannot be sucked up with such thin tubing. Only Manuvac (second 'thicker' tubing of 20 mm), the Ambu Twin and the Vitalograph Aspirator (endotracheal cathether as 'suction tubing') provide the essential option of using big-bore tubing. When the catheter tip is removed from the Ambu Uni-Suction the thick tubing allows the suction of particles (vomit).

The tubing length of more than 1 m required for pedal-operated pumps (Ambu, Söhngen) is a problem, but probably one that has to be accepted. The problem of dismantling the tubing and stowing it away again has been solved differently by all the manufacturers. In some products only part of the tubing is storable in a spacesaving and 'proper' manner (Weinmann), and in others there is no facility for fixing of the tubing (Söhngen).

With respect to the power consumption required for operation the devices fall into two technical design categories. While one group always requires the same pedal pressure independent of material (air, water etc.) being sucked out (Ambu Minipump, Söhngen, Vitalograph), the other group (Ambu Uni-Suction, Manuvac, Ambu Twin) required differentiated pedal power dependent upon aspirate.

On the whole, the power needed to drive the Ambu Minipump and the Söhngen pump must be considered too high. The power needs of the other devices are all within limits allowing suction over longer periods.

With respect to the maximum attainable vacuum there was no difference of any relevance between the devices. Also the time delay to establish the vacuum required for suction (approx. 0·3 bar) was in accordance with the measurements made by other researchers (ECRI, 1979; Dick, 1985) for all devices, i.e. in the very acceptable range of a few seconds.

A further criterion for the evaluation of the devices is to measure the volume aspirable by one pedal push. The long-stroke spring-loaded pumps (Söhngen, Ambu Minipump) are the most effective ones in this test due to their technical design. Also the Ambu Uni-Suction, the Manuvac and the Ambu Twin gave

satisfactory results. The small Vitalograph Aspirator, however, clearly fell short (Rossi *et al.*, 1983).

The efficiency of a pump in an emergency situation is represented by its speed to suction considerable amounts of fluids. The ability of the Ambu Twin pump and Uni-Suction to aspirate 250 ml in a few seconds indicates a good performance.

Another important criterion is the measurement of the maximum airflow (ECRI, 1979; Dick, 1985). A device can be considered suitable only when it has sufficient efficiency to aspirate when the suction tip is not directly immersed in the fluid to be aspirated. Also material in the proximity must be evacuated by a high flow and travel up the tubing ('vacuum cleaner effect').

At a pump frequency of 2 Hz (corresponding to 120 piston cycles min^{-1}) and at maximum speed the flow attained with the Ambu Twin was highest. In this context it should be borne in mind that due to the special design principle of the Ambu Twin pump two cycles are performed per stroke while all others have a one piston-cycle only (ECRI, 1979; Silverston, 1980, Thiemens, 1980). The Ambu Uni-Suction and Minipump as well as the Söhngen and the Weinmann pump achieved results that were comparable with each other. The efficiency of the Vitagraph Aspirator was much lower indicating an insufficient function.

CONCLUSIONS

All the devices tested have limitations and shortcomings.

The Ambu Minipump and the Söhngen product offer no possibility of using big-bore suction tubing and consequently their suitability for emergency situations is drastically reduced. Also the power requirement is high, the efficiency low and a second helper is needed for the operation. The Vitalograph Aspirator is insufficient. The Manuvac is much better in all aspects of performance.

The highest marks are given to the Ambu Twin. Dimensions and weight are suitable for common practice. The suction capacity was the highest of all devices tested. The abandonment of vulnerable valve systems and the simple and easy-to-clean design are further important characteristics.

ACKNOWLEDGEMENT

We are grateful to the manufacturers for their kindness in making the devices available during the time of the study.

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