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Optimum Vacuum Pressures for Lipolysis

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Abstract. The author presents a method to test the adequacy of any suction machine pump used in lipolysis surgery, regardless of the altitude and/or sea level of the operating room physical conditions. Surgeons can, therefore, subject any vacuum pump to a vaporization test and thereby ensure its adequacy for lipolysis techniques.

Key words: Lipolysis — Lipectomy — Suction machines — Laws of physics — Atmospheric pressure — Altitude differences

Interest among plastic surgeons in blunt suction lipectomy in North America has been increasing since October 1982. Although other surgeons had previously reported techniques for localized fatty removals using suction assistance [3, 4, 6] it was not until the presentation by Illouz and Fournier at the ASPRS annual meeting in Hawaii in October 1982, that many North American surgeons began to consider suction lipectomy as a real possibility.

Many surgeons attempting to embrace the general technique know little about the physics of the procedure and have not been exposed to Illouz' reasoning and experience. There has been controversy as to the suction pressures necessary to perform "suction lipectomy." On the one hand, Illouz states that pressures close to 1 atmosphere (30 in or 76 cm Hg) are necessary to perform the procedure properly. Characteristic of his procedure are blunt cannulas with blunt openings, individual tunnels in the fat, and closed technique (no air leak). He has described this well in his articles in French [2]. A recent article by the present author [1] describes the technique in English. Furthermore, the Educational Foundation (EF-ASPRS) basic videotape on lipolysis demonstrates the technique clearly.

On the other hand, Kesselring has stated that 0.5 atmosphere (15 in or 38 cm Hg) is enough suction pressure for his technique. Characteristic of his technique (as seen at the Educational Foundation Symposium in Los Angeles in April 1983) are an air leak to the operated space, confluency of the spaces, and sharp currettes to carve away the fat.

At the same symposium, Courtiss stated that the suction pressure was unimportant. As viewed on his videotape presented at ASAPS in April 1983, his technique appeared to have an air leak to the operated space and sharp instruments were used. In a further opinion, Teimourian has indicated that a very high vacuum pressure is necessary for adequate performance. Teimourian's present technique appears to be a closed technique [5].

Clinical Trials

First Clinical Trial

The following clinical comparison was performed at a near-sea level, American West Coast city on a patient desiring removal of iliac crest fatty tissue. The patient had the left side removed with a blunt no. 10 Illouz cannula attached to a Power Source vacuum pump providing 76 cm or 29.9 in of Hg or 0.99 atmosphere. The right side was removed with a Morwel pump, serial no. S-66, with a blunt Morwel

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no. 10 cannula. The Morwel pump provided 66 cm or 26 in of Hg or 0.86 atmosphere. Both sides were performed as a closed technique (Illouz).

Three plastic surgeon observers noted the following: (1) On the right side (Morwel pump), the flow of fat fragments was very slow down the connecting tube to the collection bottle compared to the left side (Power Source). (2) There was hardly any "boiling" (vaporization) of tissue fluids in the connecting tube with the Morwel pump but rapid "boiling" with the Power Source pump. (3) It required more than twice as long to remove the fat with many more passes of the cannula using the Morwel pump than with the Power Source pump. In order to reduce the trauma to the patient's tissue, the right side, in fact, was completed using the Power Source pump.

Second Clinical Trial

In the second clinical comparison, a Berkeley type V suction pump, 10 years old, was used on the right thigh while the Power Source pump was used on the left thigh. The Berkeley V pulled 73 cm, 28.8 in or 0.96 atmosphere of suction pressure, while the Power Source pump pulled 76 cm (30 in) Hg or 0.99 atmosphere.

The three observers noted the following: (1) The flow of fat fragments was more nearly equal for both machines. (2) There was more nearly equal "boiling" (vaporization) of tissue fluids for both machines. (3) There was less difference between the removal times for the two machines than in trial no. 1.

Experimental Studies

First Experiment

To compare the suction pressure characteristics of the three machines, the following experiment was carried out. Each machine's pump connector line to its suction bottle was instead connected to a 1,600-cc Berkeley V collector bottle and the pressure of the Berkeley gauge was used to record the pressure obtained with each machine in turn. Thus, the volume of air to be evacuated was constant, the gauge was the same, and the length of interconnect tubing was kept to a minimum. The 3-test average pressure for each machine was as follows: Morwel S-66, 66 cm Hg or 25.8 in Hg or 0.86 atmosphere; Berkeley V, 73 cm Hg or 28.8 in Hg or 0.96 atmosphere; and Power Source PS-1, 75.5 cm Hg or 29.7 in Hg or 0.99 atmosphere.

Second Experiment

The next experiment was to compare the length of time required to reach full suction pressure of which each machine was capable. The average elapsed time, based on 3 tests, for each machine was: Morwel S-66, 17 sec to reach 66 cm Hg; Berkeley V, 7 sec to reach 73 cm Hg; and Power Source PS-1, 12 sec to reach 75.5 cm Hg.

Another way to look at this same data is the length of time to reach each level of pressure. This is summarized in Table 1.

Third Experiment

The next experiment carried out was to test the ability of each machine to vaporize tap water (circa 20°C).

While the Power Source pump caused the water to boil, neither the Morwel nor the Berkeley would cause the water to "boil" (vaporize). The vaporization pressure of water at various temperatures is given in Table 2. As this table indicates, to achieve less than 17 mm Hg residual pressure at sea level would require a suction pump producing 760 mm − 17 mm, or 743 mm, suction pressure. Only the two-stage vane pump in the Power Source unit accomplished a level high enough to do this.

Relevant Principles of Physics

The Effect of Altitude

Table 3 compares the various ways atmospheric air pressure can be expressed. The column of air above us out into space has weight. In 1643 Evangelista Torricelli filled a glass tube closed at one end with mercury and everted it with the open end in a cup of mercury. The mercury will fall in the tube until it is 76 cm (760 mm) or 29.9 inches high. Torricelli drew the conclusion that the column of air pressure on the surface of the mercury in the cup was equal to the pressure of the column of mercury pressing out against the column of air. The device persists to this day in the form of mercury barometers. Most measurements are made with gauges which work by connecting a metal chamber to the source of suction. The chamber is made of pliable metal and as the inside pressure changes the chamber wall moves in or out (much like a balloon). By connecting this movement to a dial and a scale, the change in pressure can be charted. The outside atmospheric pressure is the reference, however, and this value, of course, changes both in relation to altitude and weather.

Table 1. The length of time (in sec) needed to reach a given level of pressure for three vacuum pumps (3-test average).

	66 cm	73 cm	75.5 cm
Morwell S-66	17	–	–
Berkeley V	5	7	–
Power Source	6	8	12

Table 2. The vaporization pressure of water at various temperatures.

Temperature (°C)	Pressure (mm hg)
15	13
20	17.5
25	24
30	32
35	42
37	47
40	55

Table 3. Atmospheric air pressure for several altitudes, expressed in alternate terms.

	mm of Hg	in of Hg	g/cm²	lbs/in²
Sea level	760	29.9	1,034	14.7
1,000 ft	734	28.9	999	14.2
2,000 ft	706	27.8	961	13.7
3,000 ft	680	26.8	926	13.2
4,000 ft	655	25.8	892	12.7
5,000 ft	632	24.9	861	12.2
6,000 ft	607	23.9	826	11.7
7,000 ft	584	23.0	795	11.3
8,000 ft	564	22.2	768	10.9
9,000 ft	541	21.3	737	10.5
10,000 ft	521	20.5	709	10.1

At sea level the air column above us will support 76 cm of Hg. As we climb from sea level the pressure falls, until at 10,000 ft the pressure is 52.1 cm (521 mm) of Hg. This fall is not exactly arithmetical but for practical purposes the fall illustrated in Table 3 is sufficient.

To convert the column of mercury to g/cm², multiply the specific gravity of mercury (13.6 g/cm³) by the number of centimeters of mercury. Thus:

$$76 \text{ cm} \times 13.6 \text{ g/cm}^2 = 1033.6 \text{ g/cm}^2$$

Another measurement that may be confusing and ought not to be used in discussions of these pumps is the millibar. The U.S. Weather Service defined a bar in 1939 as the pressure equivalent to 75.01 cm of mercury (29.53 in Hg). A millibar equals 1/1,000 of a bar. Thus, 76 cm of mercury (760 mm Hg) or 1 atmosphere is about 1,020 millibar. Because the value of this unit is so similar to the metric expressions of grams per square centimeter, many confuse the one with the other.

Once understood, this prevents the confusion between the two scales. On the European pumps, g/cm² is the usual mode of expression. The Berkeley pumps use mm or cm of mercury. Many small American manufacturers use gauges marked in inches of mercury since these gauges are inexpensive (and ± 10% accuracy). Ideally, grams per square centimeter or millimeters or centimeters of mercury should be used.

The Torr

One torr is the pressure necessary to support a column of mercury 1 mm high at 0°C and standard gravity. This unit is easily confused with the way we normally speak of pressure in mm of mercury. This measurement is unrelated to the surrounding air pressure and is an absolute value. This absolute pressure is different from what we read on the gauge of the suction pump, as explained below.

When we state that the Berkeley V pump, at sea level, provides a suction pressure of 730 mm of Hg what we really mean is that the pressure remaining on the inside of the system is 30 mm of Hg (760 mm − 730 mm = 30 mm). If we would place the cup of mercury at the base of the mercury barometer on the inside of the suction system and turn the pump on, as the air molecules were extracted, the mercury column would fall from 760 mm to 30 mm of Hg. Since the pump cannot extract more molecules, the remaining molecules are exerting a pressure sufficient to hold up a column of mercury 30 mm high. It would be 30 torr whether the machine was on top of a mountain or at sea level or deep in a mine shaft.

Discussion

From Table 2, we know that water at 20°C (tap water) has a vapor pressure of 17.5 mm Hg. Thus, in our experiment using the Berkeley V pump, 30 mm Hg pressure remained in the system, which was greater than the vapor pressure of the water. Thus, the water did not "boil" or vaporize.

In the surgical patient, however, the tissue fluids were at 37°C. The vapor pressure of water (solute elevates the boiling point somewhat) at 37°C is 47 mm. Thus, a 30-mm pressure remaining in the system is insufficient to prevent vaporization and the tissue fluid "boils" when the Berkeley V machine is used in the surgical patient.

The gauges on all machines are, in fact, measuring the difference between the pressure remaining in the system and the outside air pressure but not the pressure in the system directly. In that sense, significant elevation above sea level gives a false impression of the actual vacuum in the system.

For example, a surgeon is at sea level, and the atmospheric pressure is 760 mm Hg. The pump shows a gauge reading of 730 mm Hg at sea level (30 mm Hg pressure remains in the system). This is 30 torr. The lower this value, the more powerful the pump. Another surgeon is at 4,000 ft. The atmospheric pressure is 668 mm Hg. The gauge on the same pump will read the difference between 668 mm and the remaining 30 mm Hg and show a gauge reading of 638 mm. Yet the true pressure within the system remains at 30 mm or 30 torr just as it was at sea level. The apparent pressure on the gauge, however, will read only 638 mm. The surgeon can use Table 3 to correct for altitude and calculate the capability in torr of the pump.

Testing the Pump

A simple test can confirm these findings with any suction pump on the market and show exactly what residual pressure the pump is capable of producing at any altitude. It can be carried out as follows:

1. Obtain an accurate thermometer in degrees Celsius such as a dark room thermometer at a photo store.
2. Place 2 in of water in the pump collection bottle. Begin with warm water at 40°C.
3. Turn on the machine with the aspiration opening closed and note if the water boils. If it does, the machine has a lower residual pressure than the vapor pressure of water at 40°C, which is 55 mm Hg (or 55 torr).
4. Keep the pump going until the water ceases to boil. As vaporization occurs, the temperature of the water will fall because of the heat required (539 calories per gram).
5. Measure the water temperature with the thermometer.
6. Look up that temperature on Table 2. The residual pressure can be read from the table. A high-vacuum pump will vaporize water at 20°C or less.

Conclusion

If the residual pressure that the vacuum pump develops is sufficient to vaporize tissue fluids, the surgeon will use fewer strokes to evacuate the fat. This saves anesthesia time and surgeon energy. The saving of time and physical effort was demonstrated conclusively in the clinical experiments. It is a reasonable supposition that fewer thrusts results in less injury to vessels, nerves, and septi and hence fewer complications.

References

1. Hetter GP: Experience with "lipolysis": The Illouz technique of blunt suction lipectomy in North America. Aesth Plast Surg **7**:69, 1983
2. Illouz YG: Reflexions apres 4 ans ½ d'experience et 800 cas de ma technique de lipolyse. Rev Chir Esthet Fr **6**:27, 1982
3. Kesserling VK, Mayer R: Suction curette for removal of excessive local deposits of subcutaneous fat. Plast Reconstr Surg **62**:305, 1978
4. Schrudde J: Lipexheresis for the correction of local adiposity. Cong Int Soc Aesth Plast Surg, Rio de Janeiro, 1972. Int J Aesth Plast Surg 1972
5. Teimorian B, Adham M, Gulin S, Shapiro C: Suction lipectomy—a review of 200 patients over a six-year period and a study of the technique on cadavers. Ann Plast Surg **11**:93, 1983
6. Teimorian B, Fisher JB: Suction curettage to remove excess fat for body contouring. Plast Reconstr Surg **68**:50, 1981