Aesth. Plast. Surg. 24:395–400, 2000
DOI: 10.1007/s002660010066

Aesthetic Plastic Surgery

Comparative Evaluation of Traditional, Ultrasonic, and Pneumatic Assisted Lipoplasty: Analysis of Local and Systemic Effects, Efficacy, and Costs of These Methods

Nicolò Scuderi, M.D., Guido Paolini, M.D., Francesca Romana Grippaudo, M.D., and Stefania Tenna, M.D.

Rome, Italy

Abstract. Recently ultrasound assisted liposuction (UAL) and pneumatic assisted liposuction (PAL) have been introduced as an attempt to improve the results and reduce the pitfalls of standard liposuction (SAL). Until now no studies comparing, at the same time, UAL, PAL, and SAL have been published. The aim of this study was to analyze these methods from the surgeon's point of view, focusing not only on aesthetic results but also on local and systemic trauma, efficacy, handling, and cost. Forty-five cosmetic patients affected by local lipodystrophy, divided into three equal groups, have undergone liposuction with the three above-mentioned techniques. Quantitative and qualitative analysis of lipoaspirates, together with blood chemistry, local and systemic complications, time to aspirate 100 cm^3, distress, fatigue, and costs of the procedures, has been recorded. Our results showed bloodier lipoaspirates in SAL and a higher percentage of triglycerides in UAL lipoaspirates. Blood tests revealed a slight decrease in the postoperative Hb in SAL only. Early complications observed were four erythemas in PAL, three ecchymoses in SAL, and one long-lasting edema in UAL. Aesthetic results rated by independent viewers were similar for all methods. Efficacy was higher in the PAL group (4 min × 100 cm^3 fat aspirated) than in SAL (7 min × 100 cm^3 fat) and UAL (10 min × 100 cm^3 fat). Surgeon's distress was higher in PAL than in SAL and UAL. Surgeon's fatigue was much lower in the PAL group than in the others. Costs expressed as multiples of 1 unit (1 unit = $500 U.S.) were highest for UAL, low for PAL, and lowest for SAL. In conclusion, PAL and UAL caused reduced vascular injury, UAL being more selective for adipocyte removal. Complications of UAL and PAL were mostly related to the longer learning curve of these methods. The UAL procedure was much more expensive than PAL and, especially, SAL. PAL proved to be a handy technique, with the most favorable cost/benefit ratio, and seems to be the best option for busy liposuction practices or fast office procedures, even though the choice of the ideal technique always depends on the surgeon's preference.

Key words: Standard liposuction—Ultrasonic assisted liposuction—Pneumatic assisted liposuction

Correspondence to Guido Paolini, M.D., Viale di Villa Massimo 1, 00161-Rome, Italy; e-mail: gpaolini@jumpy.it

In the past decades the popularity of suction assisted lipoplasty has greatly increased and liposuction has become the most performed aesthetic procedure in both the United States and Europe. The success has stimulated its technical evolution from the simple aspiration of fat to more sophisticated body sculpturing, raising patients' and surgeons' expectations [3]. However, this operation remains not particularly beloved by surgeons because it is repetitive, tiring, and not creative and it is frequently performed just because it is highly remunerative. Aesthetic results of standard assisted liposuction (SAL) are overall considered extremely satisfactory [2,3,5], but attention today is also focused on the safety [4,5] and cost/benefit ratio of the surgical procedure. Recently, new technologies such as ultrasound assisted lipoplasty (UAL) [11] and pneumatic assisted lipoplasty (PAL) [2] have promised reduced invasiveness, complication rate, and surgeon distress.

To our knowledge no comprehensive study comparing, at the same time, UAL, PAL, and SAL has been published [2,3,5,9].

The aim of the present study is to analyze the different devices from the surgeon's point of view, verifying the proposed reduced trauma and surgeon distress and comparing the safety, efficacy, handling, and costs of each method.

Materials and Methods

Between 1997 and 1999 a comparative trial of SAL, UAL, and PAL was set up at the Department of Plastic Surgery of the University of Rome La Sapienza. Forty-five cosmetic patients in good general condition (ASA class 1 according to American Society of Anesthesiology status), with a body mass index of 25 and local lipodystrophy on the thighs and knees, were enrolled. Cosmetic patients of average body size, in good general condition, and with localized fat deposits undergoing limited fat removal (less than 1500 cm^3) were the selection criteria in order to reduce the variables affecting systemic trauma. The overall male-to-female ratio was 1:4, and ages ranged from 20 to 50 years (mean value, 32 years). Patients were randomly divided into three equal groups according to surgical procedure: group A, patients treated with the standard technique (SAL); group B, patients treated with UAL; and group C, patients treated with PAL. All patients were operated on by the same surgical team, with a standardized anesthetic procedure and intraoperative and postoperative care. Under general anesthesia an isotonic solution (500 ml 0.9% normal saline + 2 ml 1:1000 epinephrine + 10 ml 2% bupivacaine) was injected preoperatively according to standard superwet technique (1:1 infiltration-to-aspiration ratio). The mean infiltration volume was 1300 ± 200 cm^3.

Removal of fat was performed with a criss-cross technique on the superficial and deep plane using 3.5-mm blunt triport cannulas for SAL. The Contour Genesis System was used for UAL, with 4.0- and 5.0-mm hollow cannulas at 75% power, followed by removal of sonicated fat with low aspiration. The Microaire PAD 100 with 3.8-mm triport cannulas was used for PAL. Systemic antibiotics (ceftriaxone, 2 g/per day iv) were started intraoperatively and continued together with antiinflammatory drugs (nimesulide, 150 g/per day per os) for 3 days postoperatively. An elastic garment was always worn postoperatively for up to 6 weeks. Follow-up ranged from 12 to 30 months, with a mean value of 19 months.

The aspirated material, collected in sterile containers, was mixed and a homogeneous sample of 300 cm^3 was examined to evaluate local trauma. The infranatant liquid was tested for hemoglobin (Hb), hematocrit (Hct), triglycerides (Try), and cholesterol (Cho) to investigate the trauma on vessels and fat tissue. Samples from the supernatant were stained with hematoxylin–eosin and histologically examined by optical microscopy at ×4.0 magnification to assess cellular damage. To determine systemic effects, blood samples were taken preoperatively and 24 h postoperatively for evaluation of blood (Hb, Hct, LDH, CPK) and lipid balances (Cho, Try, LDL, HDL, lipid profile b, pre/b, WBL). Patients returned for follow-up at 3 days, 10 days, and 1, 3, and 12 months. Early and late complications were recorded. Aesthetic results were evaluated by a panel of five "blinded" viewers that was asked to examine pre- and postoperative photographs and to try also to identify the surgical procedure used. Their evaluation was rated on a 1-to-10 visual analogue scale (VAS) [10]. Efficacy, handling, and costs were then compared.

Efficacy was rated by average operative time and average time to aspirate 100 cm^3 of fat. Handling was evaluated considering the learning curve, the distress, and the fatigue of the method used. Surgeon's discomfort and fatigue were each subjectively rated on a 1-to-10 VAS, with 10 representing the most noisy and tiring procedure.

To compare overall expenses for each method, all costs were converted to units, with 1 unit equal to $500 U.S. The cost of a single procedure was calculated by summing the costs of the equipment divided by the number of patients treated, the average cost of the operating room, and the average cost of hospitalization for an overnight patient.

Results

The mean infiltration and aspiration volume was 1300 ± 200 cm^3 in all groups.

SAL (Fig. 1a) and PAL aspirates (Fig. 1b) were composed of almost-equal parts of supernatant (50%) and infranatant (50%): the supernatant was composed of preserved yellow fat lobules, while the infranatant was an acellular fluid, bloodier in the SAL group. UAL aspirates (Fig. 1c) consisted of four-fifths supernatant, which was composed of a homogeneous yellowish acellular fat mass. The infranatant made up one-fifth of the total and was a pale reddish color.

Biochemical analysis of the infranatants showed a mean Hb content of 5.1 g/dl in the SAL group, 1.4 g/dl in the UAL group, and 0.96 g/dl in the PAL group (Table 1 and Fig. 2). The Hb mode value was 6.35 g/dl in the SAL group, 0.73 g/dl in the UAL group, and 0.43 g/dl in the PAL group.

The mean Try content was 143 mg/dl in the SAL group, with a mode value of 200.7 mg/dl; 1271.6 mg/dl in the UAL group, with a mode value of 1033.18 mg/dl; and 220.7 mg/dl in the PAL group, with a mode value of 137.7 mg/dl (Table 2 and Fig. 3).

As reported by Adamo et al. [1] in 1997, the histology of the supernatant samples showed nests of fat cells with preservation of membrane integrity in the SAL group (Fig. 4a) and a shrinkage of membranes with resulting adipocyte disruption in the UAL group. Analysis of PAL supernatant samples showed agglomerates of preserved fat cells similar to those in the SAL group (Fig. 4b).

Comparative evaluation of preoperative and 24-h postoperative systemic blood and lipid balances showed values in the normal range, except for a slight decrease in Hb in the postoperative controls of the SAL group (1 g/dl < Hb > 1.9 g/dl).

A postoperative increase in CPK enzyme, ranging from 29 to 58% of the preoperative value, was noted in all groups and particularly in UAL patients. No significant variation in other parameters was observed.

Early local complications recorded from day 3 to day 10 were four cases of localized erythema in the PAL

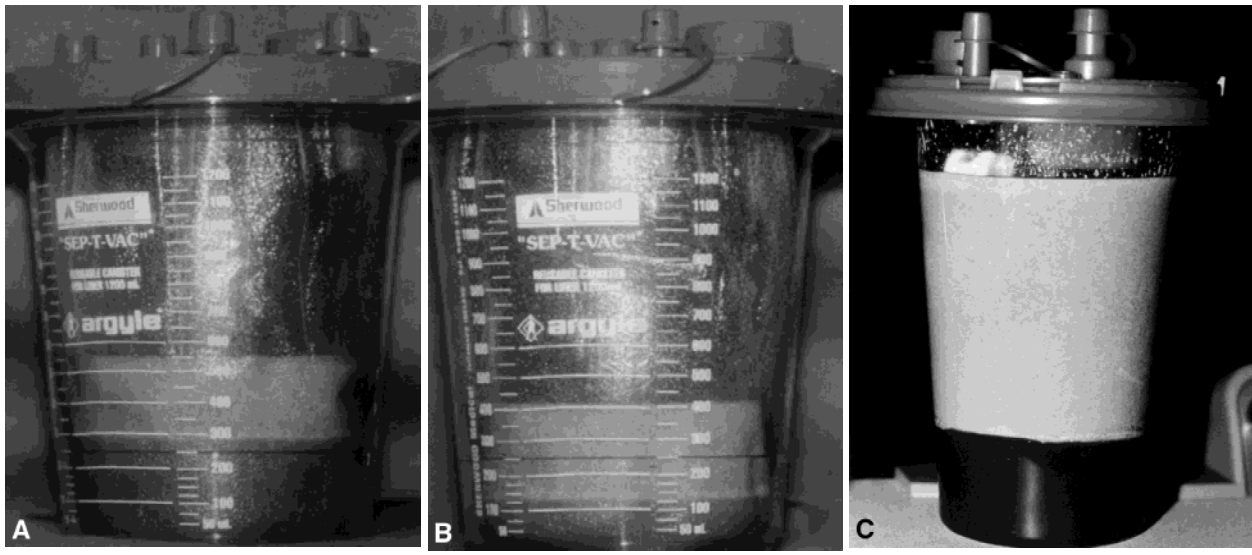


Fig. 1a. Sample of SAL lipoaspirate. Infranatant and supernatant are in almost-equal parts.
Fig. 1b. Sample of PAL lipoaspirate. Infranatant and supranatant are in almost-equal parts.
Fig. 1c. Sample of UAL lipoaspirate. Supernatant is almost four-fifths of the whole.

Table 1. Hemoglobin content (g/dl) in infranatants

Patient No.	SAL	UAL	PAL
1	6.3	0.8	2.15
2	5.2	0.6	2
3	6.2	0.9	0.20
4	4.2	0.7	0.35
5	5.7	0.6	0.9
6	4.8	0.8	0.4
7	6.5	0.6	0.8
8	6.4	0.7	0.6
9	6.6	0.9	0.75
10	0.6	1.6	0.75
11	4.9	2.50	0.46
12	5.4	2.90	0.6
13	2.1	2.70	2.2
14	6.1	2.90	1.3
15	5.7	1.9	1

Table 2. Triglyceride content (mg/dl) in infranatants

Patient No.	SAL	UAL	PAL
1	209.5	1824.2	449.5
2	150.7	2487.5	124.7
3	237.3	2235.4	97
4	80.8	1527.4	139
5	15.9	1754.8	282.5
6	188.6	2135.6	140.3
7	135.6	1653.8	112
8	203.5	1934.7	230.5
9	141.6	1254.3	186.5
10	165.60	630.2	140
11	288.70	219.5	243.6
12	33.9	448.9	768
13	33.3	456	126
14	59.18	63.6	159
15	201.5	448.9	112

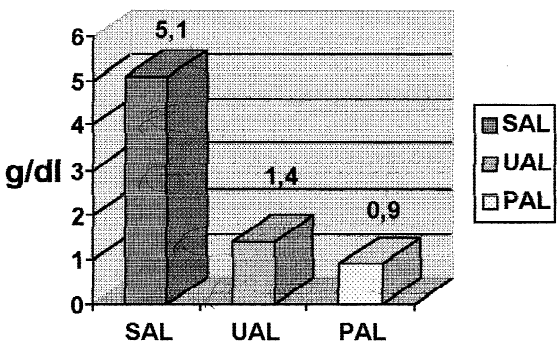


Fig. 2. Mean Hb concentration in lipoaspirate.

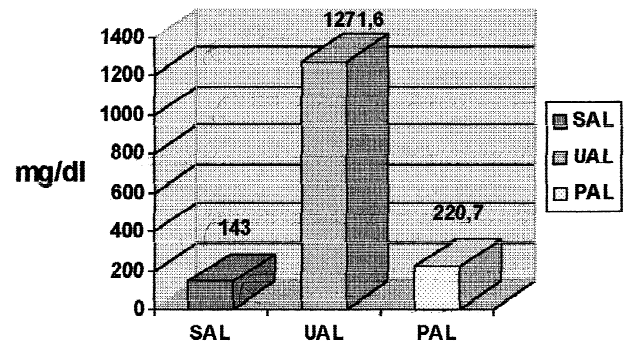
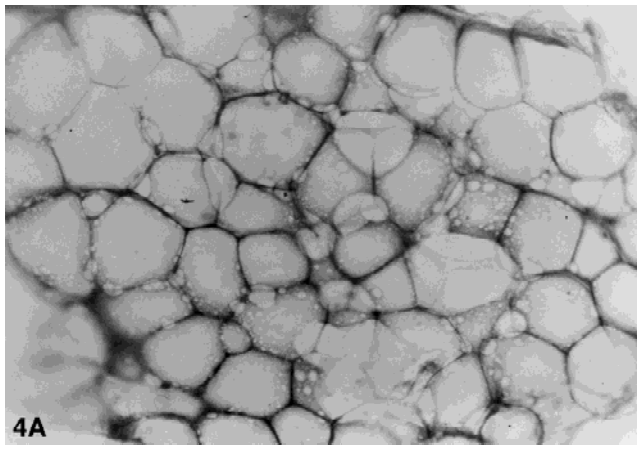


Fig. 3. Mean triglyceride concentration in lipoaspirate.



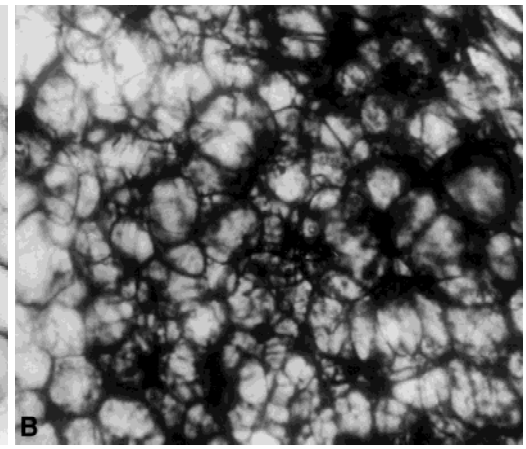


Fig. 4. Optical microscopy magnification of PAL **(a)** and SAL **(b)** supernatants. Intact fat lobules and adipocytes. H&E stain; original magnification, ×100.
Fig. 5. Localized erythema, with soreness and swelling, observed on day 3 after PAL treatment.

group (Fig. 5), three cases of ecchymosis in the SAL group, and one case of moderate lower limb edema in the UAL group.

Erythema and ecchymosis were both medically treated, disappearing in about 2 to 3 weeks, with no pigmentary changes remaining. Lower limb swelling resolved after 2 months with manual lymphatic drainage. No generic or anesthesia-related complications were observed in the short term.

No severe late complications such as sensory changes, surface irregularities, or abnormal skin contraction–retraction were observed from 1 to 12 months in all groups.

Aesthetic results assessed at 12 months by a panel of five blinded viewers were as follows: mean and mode values, respectively, were 7.9 and 7.4 for SAL, 7.2 and 6.9 for UAL, and 7.3 and 7.05 for PAL (Fig. 6). The different techniques were not easily recognizable on photographic evaluation, except for slightly larger scars at cannula insertion sites in the UAL group.

A longer learning curve was necessary for PAL and UAL.

The mean aspiration time for 100 cm^3 was 4 min for PAL, 7 min for SAL, and 10 min for UAL (Fig. 7).

The mean surgeon distress and discomfort, according to the VAS, was 6 for PAL because of noise and vibrations, 5 for UAL because of noise from the ultrasound source, and 2 for SAL because of noise from the aspiration pump only (Fig. 8). Surgeon fatigue was 8 for SAL, 5 for UAL, and 3 for PAL (Fig. 9).

Hospitalization time was 1 day for each procedure, with a corresponding cost of approximately 1 unit per patient. Mean operating time was approximately 1.5 h for PAL, 2 h for SAL and 2.5 h for UAL. The cost of the operating room for 1 h is approximately equal to 0.5 unit, corresponding to 0.75 unit for PAL, 1 unit for SAL, and 1.25 units for UAL. Equipment expenses were 1 unit for SAL cannulas, 15 units for the Microaire PAD 100 for PAL, and 90 units for the Contour Genesis System for UAL. These costs divided by the number of patients gave corresponding values of 0.06 unit for SAL, 1 unit for PAL, and 6 units for UAL.

Finally, the overall cost of a single procedure was 2.06 units for SAL, 2.75 units for PAL, and 8.25 units for UAL (Table 3 and Fig. 10).

Discussion

Fat suction was successfully accomplished with each method employed. Local trauma, dependent on the physics principles, differed.

The higher percentage of supernatant in UAL than in SAL and PAL aspirates is related either to its greater

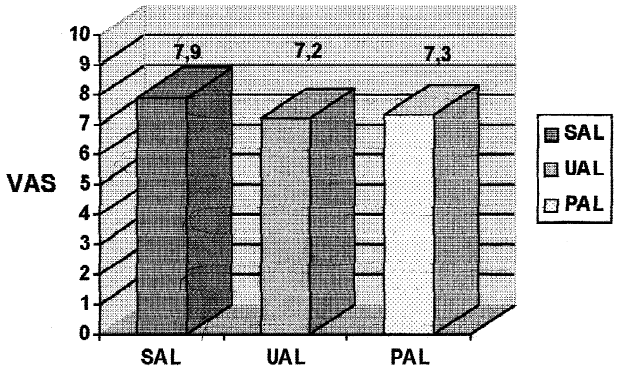


Fig. 6. Aesthetic results rated by surgeons.

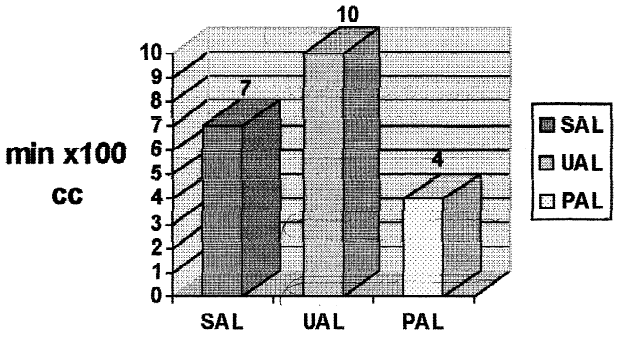


Fig. 7. Efficacy: mean time to aspirate 100 cm^3 of fat.

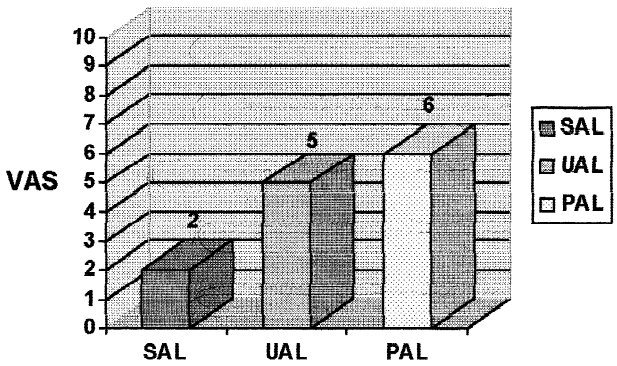


Fig. 8. Evaluation of surgeon distress.

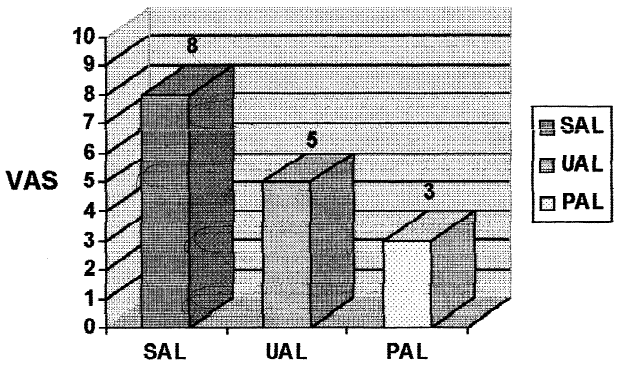


Fig. 9. Evaluation of surgeon fatigue.

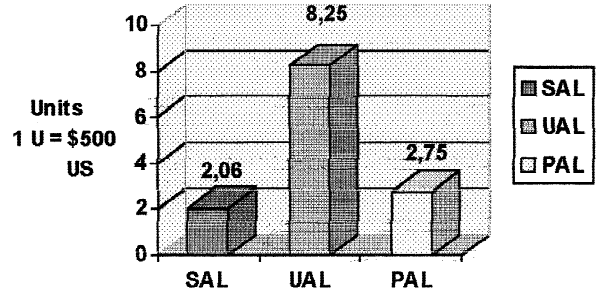


Fig. 10. Single-procedure costs.

Table 3. Overall cost for a single procedure

	Cost (units)		
	SAL	PAL	UAL
Hospitalization	1	1	1
Operating room	1	0.75	1.25
Equipment	0.06	1	6
Total	2.06	2.75	8.25

specificity for adipocyte cell reduction [1,3,9] or to the immediate fluid loss induced by the cavitation effect. The high Try value in UAL infranatants, caused by cell membrane rupture and Try egress [6], is another indirect sign of the specific adipocyte disruption induced by sonication. The low Hb content present in UAL and PAL infranatants suggested reduced trauma on blood vessels in both procedures, confirming previous observations for UAL [3] and arguing against the theory of increased vascular damage induced by the vibration of the reciprocating cannula for PAL [2]. At the same time the low Try values in PAL and SAL infranatants demonstrated the absence of a mechanical adipocyte disruption. The higher Hb content found in the SAL group validates the impression of increased vascular damage.

A direct demonstration of adipocyte disruption in UAL group was also given by optical microscope analysis.

The aspirated volume of 1500 cm^3 indicates a medium-size liposuction in which significant variations of hematic balances are not to be expected. However, serum blood and lipid balances at 24 h showed a slightly reduced Hb value (>1 g) only in the SAL group. Conforming with literature reports [3,5], a greater increase in postoperative CPK values was found in UAL patients, due to membrane lysis and intracellular enzyme relapse, but no LDH changes were noticed. No systemic changes in postoperative lipid balances were observed in UAL patients even though the increase in Try in their aspirates was consistently higher than in PAL and SAL patients.

Early complications recorded in the PAL series (four erythemas), were mainly technique-related and probably due to the learning curve of the method. In the early cases the use of a reciprocating cannula at maximum speed under the dermal layer may have produced excessive heating at the dermal interface, causing superficial

inflammation. As soon as a lower speed was used and the subdermal layer more infiltrated, the problem was overcome and a safe superficial liposculpture was performed.

The lower limb swelling occurring in the UAL group can be explained by the limited postsonication aspiration performed in an early case.

No differences in patient or surgeon satisfaction were recorded as regards the aesthetic results with all techniques.

The highest surgeon distress registered for PAL was caused by the vibration of the reciprocating cannula and the noise produced by the handle, both decreased significantly with further development of the device (PAD 200). On the other hand, UAL irritation caused by ultrasound emission, even if not exceeding the safe hearing threshold [7], was noisy and disturbing. Regarding surgeon fatigue, our experience indicated that the reciprocating movement of the PAL device creates a smoother gliding of the cannula, resulting in the least exhausting procedure. Nevertheless, the learning curve, which is longer for UAL than for PAL, must also be considered, as the easier suction could create a higher risk of overcorrection in the early cases.

The analysis of costs showed UAL to be the most expensive technique, SAL the cheapest, and PAL an affordable option.

Finally, the higher efficacy and the reduced costs of the PAL procedure proved it to have the best cost/benefit ratio.

Conclusions

The three methods examined were all valid and safe in terms of final results. All techniques can be successfully employed for the suction of limited fat deposits in cosmetic patients. The new technologies may offer wider, more specific indications and a customized patient selection.

A more selective trauma on fat tissue, with reduced vascular injury, was observed for both the UAL and the PAL groups. As already known for UAL, PAL proved to be a relatively atraumatic technique.

The limited number of cases does not allow us to draw any conclusions about the different complication rates in the three groups. Anyway, complications recorded in the PAL series seem to be due mostly to the learning curve and technique-related.

The most interesting data emerging are that PAL operative times were reduced by almost 50% compared to UAL and 25% compared to SAL. Surgeon fatigue was also lower in the PAL group, due to the easier tunneling and faster fat suction.

The overall costs of the procedure were affected mainly by equipment expenses and then by operative time.

In conclusion, surgeons with a busy practice, who usually perform medium-size liposuctions in one session or as office procedures, would benefit from use of the PAL technique. However, the choice of the ideal technique always rests with the surgeon.

References

1. Adamo C, Mazzocchi M, Rossi A, Scuderi N: Ultrasonic liposculpturing: Extrapolations from the analysis of in vivo sonicated adipose tissue. *Plast Rec Surg* **100:**220, 1997
2. Fodor PB, Vogt PA: Power-assisted lipoplasty (PAL): A clinical pilot study comparing PAL to traditional lipoplasty (TL). *Aesth Plast Surg* **23:**379, 1999
3. Fodor PB, Watson J: Personal experience with ultrasound assisted lipoplasty: A pilot study comparing ultrasound assisted lipoplasty with traditional lipoplasty. *Plast Reconstr Surg* **101:**1103, 1998
4. Gingrass MK: Lipoplasty complications and their prevention. *Clin Plast Surg* **26:**341, 1999
5. Gingrass MK, Kenkel JM: Comparing ultrasound-assisted lipoplasty with suction assisted lipoplasty. *Clin Plast Surg* **26:**283, 1999
6. Grippaudo FR, Matarese RM, Macone A, Mazzocchi M, Scuderi N: Effects of traditional and ultrasonic liposuction on adipose tissue: A biochemical approach. *Plast Reconstr Surg* **106:**197, 2000
7. Kenkel JM, Johns DF, Rohrich RJ, Adams WP, Roeser RJ: Hearing and ultrasound assisted liposuction: The effect on surgeon and patient. *Plast Reconstr Surg* **106:**150, 2000
8. Rohrich RJ, Beran SJ: Is Liposuction safe? *Plast Reconstr Surg* **104:**819, 1999
9. Rohrich RJ, Morales DE, Krueger JE, Ansari M, Ochoa O, Robinson J, Beran SJ: Comparative lipoplasty analysis of in vivo-treated adipose tissue. *Plast Reconstr Surg* **105:**2152, 2000
10. Scott J, Huskisson EC: Graphic representation of pain. *Pain* **2:**175, 1976
11. Scuderi N, De Vita R, d'Andrea F, Vonella M: Nuove prospective nella liposuzione: la lipoemulsificazione. *Giorn Chir Plast Ricostr Ed Estet* **2:**1, 1997