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# Liposuction : Review of the Techniques, Innovations and Applications

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**Key words.** Liposuction ; lipoplasty ; aesthetic surgery.

**Abstract.** Liposuction is currently the most frequently performed aesthetic operation in the world. Despite its widespread popularity, it should nevertheless be stated that it is not trivial surgery, not always benign and not as safe as intimated in the glossy office brochures. Since the initial description of liposuction, numerous changes have taken place. Today, surgical indications are well defined and the liposuction procedure is well codified. However, several surgeons and manufacturers have developed new equipment and techniques. We propose to survey all the techniques showing the real place of each of them. Their advantages and disadvantages will be discussed. The various techniques dealt with are : the wetting solution techniques, standard liposuction or Suction-Assisted Lipoplasty (SAL), internal Ultrasound-Assisted Liposuction (iUAL), VASSER assisted liposuction, external Ultrasound-Assisted Liposuction (eUAL), Laser-Assisted Liposuction (LAL), Power-Assisted Liposuction (PAL) and Vibroliposuction (VL). On the basis of this review of the literature and of our clinical experience, we conclude that VL is the safest, most effective and precise surgery that can be used in any of the modern indications for liposuction. We concluded that VL seems to have all the advantages and none of the disadvantages associated with iUAL.



## Introduction

Liposuction is currently the most frequently performed aesthetic operation in the world. Despite its widespread popularity, it should nevertheless be stated that it is not trivial surgery, not always benign and not quite as safe as intimated in the glossy office brochures. Mortality and morbidity related to liposuction procedures still exist today (1, 2).

The first surgical procedure was performed, by Dujarrier in 1921. He used a uterine curette to remove fat from the knees of a well-known ballerina, with a disastrous outcome. In the 1960s Schrudde removed subcutaneous fat deposits through stab incisions by sharp curettage (3). In 1978 Kesselring added strong suction to this sharp curettage method (4). Shortly after, Illouz replaced the curette by a blunt cannula inserted subcutaneously and connected to a vacuum pump to aspirate the fatty tissue (5). He also proposed irrigation of the subcutaneous space with a hypotonic saline solution in the belief that the fat cells would swell and rupture, but this process has never been confirmed clinically.

In the past decade, many innovations have been made and the anatomy and physiology of the fatty tissue have been studied in ever greater depth. Modern innovations in suction lipectomy include the superwet and the tumescent wetting techniques, Ultrasound–Assisted Aspiration (UAL), VASSER, Laser-Assisted Liposuction (LAL), Power Assisted Liposuction (PAL) and finally Vibroliposuction (VL).

## Indications and Patient Selection

The best results are still obtained when treating moderate localized fat deposits in a normal-weight patient which cannot be managed by diet and exercise (Fig. 1). At the present moment, the key to success is the capacity of the skin to redrape on the new adipose tissue shape, in order to avoid surface irregularities and wrinkles due to skin excess. This important property has to be evaluated preoperatively (Fig. 2).

Although a smooth, young and tight skin is a desirable criterion in patient selection, patients with less elastic or older skin, skin wrinkling or multiple fine irregularities (cellulite) may also benefit from liposuction and more specifically from superficial liposuction inducing more skin retraction (6).

Good health is a basic requirement for aesthetic body contouring procedures. Failure to screen out patients whose health is suboptimal is one of the important contributing factors to serious morbidity following liposuction. Most surgeons agree that liposuction is NOT a weight loss technique (7). However, it can be used for patients who far exceed ideal body weight, but the results are less dramatic, although very helpful in improving the fit of clothing in problem areas, such as the hips.

## General Aspects

Numerous changes have taken place in the original technique of suction lipectomy. The original large, sharp,

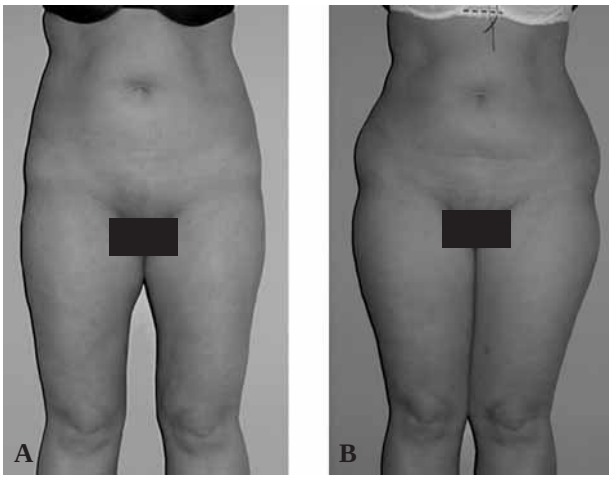

*Fig. 1*
A. This is an excellent case for limited liposuction of fat deposits located at the top of the thighs and on the hips, with excellent skin quality ; B. At 6 months post-operative smoother curves can be observed with excellent skin retraction and no depression or irregularity.

single-hole cannulas were replaced by smaller cannulas with blunt tips and multiple holes (Fig. 3). Sharp tips are more likely to penetrate the fascia or skin, whereas a rounded tip permits easy movement through the tissues with less danger of penetration or neurovascular bundle damages. The distal aperture should be positioned behind the tip ; this has the advantage that skin can be lifted by the tip of the cannula without direct subcutaneous fat removal. Multiple holes increase the efficiency of fat removal, resulting in fewer passes of the cannula and less tissue trauma.

As regards the diameter of the cannula, no single diameter suits all anatomic areas. Originally, traditional liposuction was performed using very large cannulas (10 mm) which had to be kept in the deep fat to avoid surface irregularities. With the advent of smaller cannulas (2-3 mm) and different tip configurations, surgeons can work closer to the skin without creating noticeable irregularities and perform liposuction of areas of sparse fat deposits. After superficial liposuction treatment of 2,500 patients, Gasperoni describes good aesthetic results on patients with “old and less elastic skin”. A skin retraction, following the superficial removal of fat deposits would be responsible for these results (8). However, most authors agree on the fact that cellulitis is not a good indication for liposuction. As a general rule, large, deep fat deposits should be treated with large-diameter cannulas (5-6 mm), and small, superficial fat deposits should be treated with small-diameter cannulas (3-4 mm). Facial suction requires cannulas of only 1.5-2.4 mm in diameter.

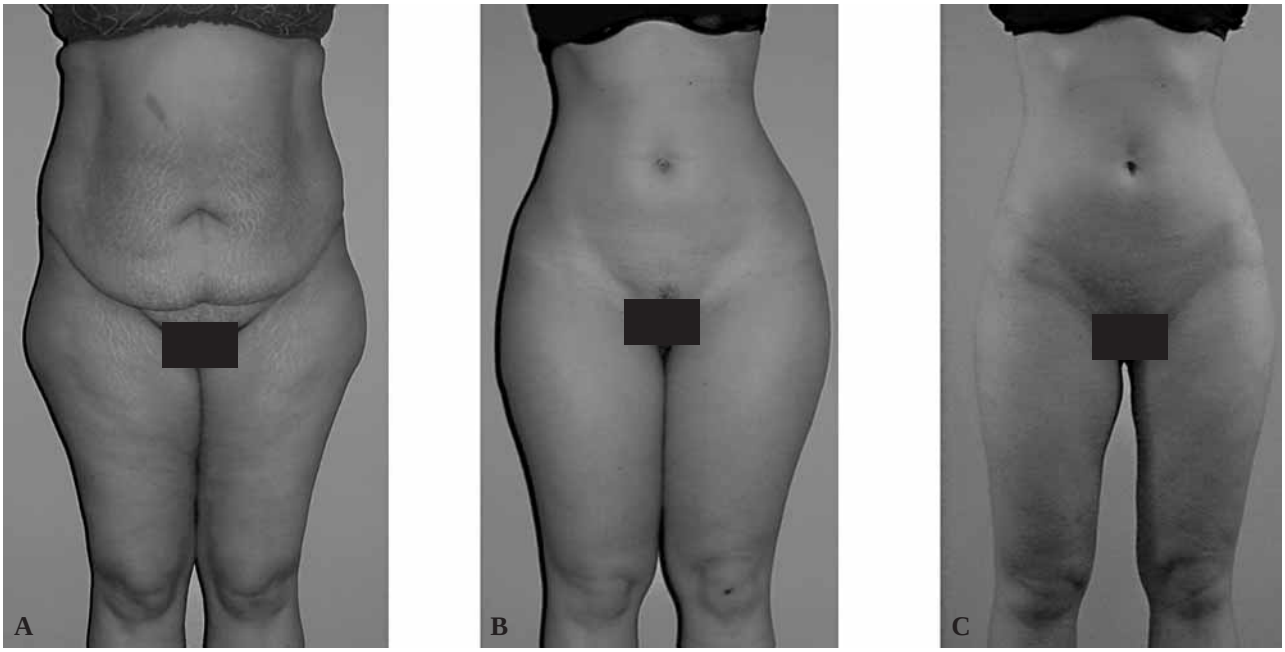

*Fig. 2*
A. This is not a good candidate for liposuction. The skin is of poor quality, aged, hardened, striated with wrinkles and poor retraction capacity ; B-C. When the patient is young, with a skin of excellent quality, an good cutaneous covering retraction can be expected and significant liposuction can be carried out with no risk.

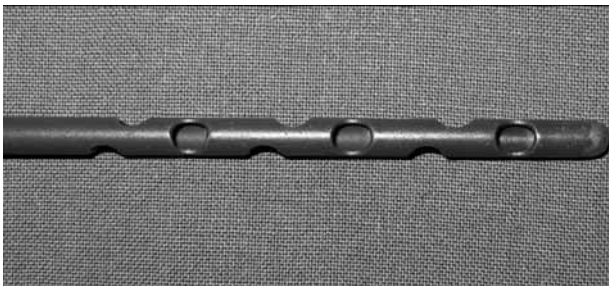

*Fig. 3*
The cannula most often used with the Lipomatic® is size 4, with a foam end and multiple holes. The nutation movements of the head and the multiple holes make for optimum fat removal during a cannula pass.

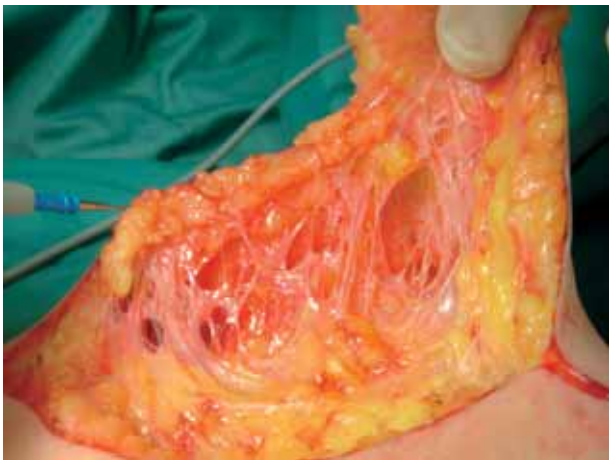

*Fig. 4*
This is a perioperative view of the subcutaneous tissue being lipoaspirated with the Lipomatic®. The cannula pass removes the fat while respecting the fascio-neuro-vascular structures.



The stab incisions into the skin are placed adjacent to the area to be treated, concealed in a natural fold. The incisions should be slightly longer than the cannula diameter to avoid skin trauma and burns. Liposuction creates a discontinuous cavity or multiple small cavities. More accurately the treated area is characterized by a fascia-neurovascular-lymphatic framework from which the fat has been removed (Fig. 4).

After infiltration, the cannula is inserted for suctioning. Keeping the tip in the central deep fat permits contour reduction, leaving the superficial fat undisturbed to provide smooth, soft cover above the treated area. If superficial liposuction is planned, it will be performed after the deep fat liposuction. However, some anatomic areas may only have a single, thin fatty layer, so the surgeon has to direct the tip immediately below the skin surface.

Before concluding the procedure, the edges have to be palpated in the search for lumps and abrupt steps from treated to untreated areas. If present, smoothing can be performed by removing small amounts of fat in the transition zone using a fine-diameter cannula. General guidelines call for a halt when skin flaccidity precludes secondary shrinkage. The final contour will not be determined by the amount of fat removed, but rather by how much is still in place at the end of the operation.

**Wetting solution techniques**

The terminology relating to infiltration of the subcutaneous fat before liposuction includes : the dry, the wet, the superwet and the tumescent technique. The dry and wet techniques are now of historical interest only. In the dry technique, liposuction was performed without the addition of subcutaneous solution injection (9). The wet technique was introduced by Illouz in 1984 and consisted of injecting hypotonic saline solution. He attempted to induce swelling and hydrolysis of in vivo fat cells, i.e., “lypolysis” (5). There remains no clinical evidence to support this action mechanism, and the use of hypotonic saline has fallen into disfavour. The use of saline infiltration, however, gained popularity, and by the early 1980s the majority of surgeons were using the wet technique. They infiltrated 200 to 300 cc of saline, with or without additives (Lidocaine and Adrenaline), into a surgical area. These two techniques were both abandoned because of excessive blood loss, the suction aspirate containing 20-45% of blood in the dry technique (9-11) and 4-30% in the wet technique (12).

New solutions appeared with the superwet technique (13, 14) and the tumescent technique (15), which dramatically improved the safety of liposuction. The superwet technique is defined as 1ml of infiltrate per 1 ml of aspirate. The tumescent technique is defined as 2-3 cc of infiltrate per 1cc of aspirate. In these methods, the subcutaneous fat is infiltrated with large volumes of a mixture of lidocaine, adrenaline, sodium bicarbonate and normal saline before fat removal. Blood loss dropped to 1 percent of the aspirate, which allows a larger volume of fat to be safely aspirated (14). Another advantage is the reduced need for intravenous administration of fluids perioperatively (12).

Lidocaine may be used at dosages higher than those listed in the standard references (7 mg/kg or 500 mg maximum doses). Several studies have shown that much larger doses can be used safely. Pitman has injected up to 2000 mg of dilute lidocaine and epinephrine over 10 minutes without any problems (16), Klein used doses of 35 mg/kg with the tumescent technique (17) and Burk 28 mg/kg (18). Rohrich believes that 35 mg/kg is the safe limit for liposuction with the tumescent technique (14).

Epinephrine induces vasoconstriction, improving haemostasis, delays absorption of the anaesthetic agent, prolongs its effect to four times as long, decreases the amount needed and reduces the risk of lidocaine toxicity. It is recommended that 0.7 mg/kg not be exceeded, although doses as high as 10 mg already have been used safely (18).

There is still no consensus regarding the optimal composition and amount of subcutaneous infiltration solution for safety or for optimal aesthetic results. With these techniques, the focus has shifted from hypovolemia prevention to the prevention of fluid overload (15). The risk of fluid overload and congestive heart failure seems to be lower with the superwet technique. There are no proofs in the literature supporting advantages, with respect to safety and efficacy, when ratios greater than 1/1 are used (14).

**Internal Ultrasound-assisted lipoplasty (iUAL)**

Some additional pieces of equipment are required for iUAL, compared with the SAL (19). As a minimum, these devices include an ultrasonic generator that converts the standard electricity supply into high-frequency electrical energy. The generator is connected to a surgical handpiece, which contains a piezoelectric crystal that converts electrical energy into a mechanical vibration. A titanium probe (solid or hollow) attached to the handpiece amplifies these vibrations and transmits it to its tip, which produces alternately reduced and increased pressure in the surrounding fluid of the adipose tissue. This process causes a "cavitation process" which induces adipose cell wall rupture. The triglyceride released combined with the tumescent solution and the interstitial fluid form a stable fatty emulsion in the subcutaneous space. This emulsion can be removed with low-vacuum suction and small diameter cannulas.

The iUAL is a three-step process (19). First the subcutaneous fat is infused. The second step consists of fat emulsification with the probe vibrating at ultrasound frequency. The third step is the evacuation of emulsified fat by lipoaspiration. An aspiration function can be incorporated in the probe (hollow) to remove as much aspirate as possible while energy is being applied to emulsified fat (19). The two cardinal rules of utmost importance in iUAL to prevent thermal injury are that the ultrasound energy must be applied in a wet environment and the probe must always be kept in motion.

This technique, conceived by Zocchi in the late 1980s (20), has been promoted as an ideal method for the extraction of large volumes of fat with minimal fatigue to the surgeon, minimal blood loss, little or no bruising, and exceptional control of contour (19, 20). Difficult fibrous areas such as the male breast and back are especially well treated (19). It has been suggested that this technique causes enhanced contraction of the skin overlying the treated areas (20).

At the present time this technique is suffering from increased operating time with similar volume fat removal compared with conventional lipoplasty (21). A number of complications are also associated with this technique : skin loss (19, 22), seroma with rates as high as 50% in the initial experience in the USA (23), and peripheral nerve injury (24). Karmo *et al.* showed that blood loss using the iUAL is slightly higher even if subclinical (25). Igra *et al.* were unable to show a difference in the postoperative course or the final cosmetic result when comparing the SAL and iUAL techniques (26). After initial enthusiasm for iUAL, many surgeons have now rejected this technique. They asserted that the potential benefits do not outweigh its greater cost, need for training, and increased risk of complications. The long term consequences of iUAL are also unknown.

Fodor stated that the operating time is longer (+ 40%) and longer incisions are needed (21). Moreover, rigid cannulas are needed (making for difficulty in passing around the body curves) which are expensive due to the need for frequent replacement (one single cannula : 20 h life, 1,000 USD !). Skin protection is essential, in the form of plastic protectors.

The incidence of skin slough or necrosis has been reported to be as high as 4%-6% (19). While some authors like Zocchi (20) advocate a superficial iUAL to stimulate the dermis and enhance skin retraction, others like Maxwell abandoned aggressive iUAL because of the high risk of skin necrosis (19).

The incidence of seroma is definitely higher after iUAL, compared with the negligible rate associated with SAL (0.08%) (23).

Howard *et al.* (24) examined the sensory changes after iUAL. Their analysis showed that recovery time appeared to be longer (10 weeks) compared with SAL (6 weeks). Indeed, the neurosurgical literature has documented the injurious effects of ultrasound energy on peripheral nerves (27, 28). The potential for ultrasound energy causing damage to peripheral nerves suggests that the risks of using iUAL in arms, legs, neck and face may outweigh any potential benefits. Howard *et al.* (24) recommend caution when considering iUAL in the extremities and in anatomic areas containing nerves. They found a direct correlation between the amplitude (generator setting), number of passes made, and degree of injury, noted both grossly and by walking track analysis.

Fortunately, the frequency of these complications associated with iUAL has steadily decreased thanks to greater operator experience and the use of lower ultrasonic energy levels for shorter periods of time. Many surgeons believe that it produces results superior to those obtained with SAL for large-volume removals, fibrous areas, and repeat operations (19, 20, 21, 29, 30).

**VASSER (Sound Surgical, Denver, Colo.)**

The search for an improved iUAL device has led to the introduction onto the market of the VASSER–Assisted Liposuction (21). Adjustments have been made to render the device safer. Only small-diameter solid probes (2.9 and 3.7 mm) are used and require much less ultrasound energy than the traditional iUAL systems currently used. Grooves near the tip are added to increase fragmentation efficacy. The VASSER still liquefies fat, but the risk of thermal injury (from end blows and at the insertion site) is reduced. In many ways, this new technology is more like power-assisted lipoplasty than traditional internal ultrasound-assisted lipoplasty. However, skin protection (ports and wet towels) is still needed.

**External-UAL (eUAL)**

External ultrasound application was introduced by Silberg in 1998 (31). Immediately after injecting the tumescent fluid, the ultrasonic energy transducer is placed on the area. Moderate pressure is used to help energy delivery to the deeper fat and a slow continuous motion of the transducer must be maintained (31). According to his preliminary report, the advantages of this technique were that more fat could be removed in a significantly shorter period of time, and the fat was whiter and of a looser consistency. There was less resistance to the movement of the canula, less bruising, and less post-operative swelling and discomfort (31). These results have been confirmed by other investigators (7, 32, 33).

Nearly all the complications associated with iUAL are avoided. Silberg reported one case of post-operative seroma, but otherwise no skin slough or nerve lesions (which are induced by direct contact of the probe in the iUAL) were reported (7, 31-33). The large incisions required for internal ultrasound liposuction were no longer necessary (33) and good skin retraction was also observed (33, 34). Gasperoni considers external ultrasound as an ideal complementary procedure to superficial subdermal liposuction, since the eUAL permits a more uniform aspiration of the subdermal fat layer, making skin retraction even more effective (33).

**Laser-Assisted Liposuction (LAL)**

Different kinds of LAL have recently been developed and some are still at the experimental stage. An initial type of LAL has been tested by Apfelberg (35). The operator inserts the cannula (special design, single-holed, 4-6mm diameter), activates the suction, and then depresses the foot pedal to activate the laser. The negative suction draws the fat globule into the hole of the cannula where the laser beam (YAG laser 40W) shears it off bloodlessly. Apfelberg *et al.* concluded in their multicentre study that there was no clear and significant benefit to be gained from LAL over conventional liposuction (35). The disadvantages are the slightly cumbersome and awkward equipment, and the fact that experience in laser use is essential. Safety glasses are necessary, the procedure is noisy and constant cooling is required. The only advantages are greater ease and less arm motion fatigue.

Neira used the Low-Level Laser-Assisted Lipoplasty (LLLAL) in 2000 (36). Low-level laser therapy is defined as treatment with a dose rate that causes no immediate detectable temperature rise in the treated tissue and no macroscopically visible changes in tissue structure (36). The LLLAL consists of the tumescent liposuction technique with the external application of a cold laser (635 nm and 10 mW intensity for a 6-minute period) through the skin. They demonstrated that external lower-level laser associated with tumescent infiltration of the subcutaneous tissue produces a transitory pore in the adipocyte membrane (99% of the adipocytes after 6 minutes of laser exposition), preserving the interstitium and the capillaries in particular. This allows fat to move from inside to outside the cell, placing it in the interstitial space. The release of fat by suction is facilitated, surgical trauma is diminished, ecchymosis or hematoma is reduced and patient recovery is fastened (36). However in 2004, Brown *et al.* analyzed the effect of low-level laser therapy on abdominal adipocytes before lipoplasty procedures and their results did not bear out the effect of low-level laser therapy on adipocyte structure (37).

A third innovative laser technique is the use of a pulsed Nd-YAG laser beam (1064 nm) delivered via an optical fibre of only 300 micrometers inserted in a 1 mm cannula. After lipolysis, the liquid fat is suctioned by a 3 mm cannula. Proposed indications are flaccid areas, small areas, secondary liposuction and difficult cases (38). Kuwahara showed that the ultra short stress waves generated can mechanically cavitate fat in vitro without significant damage to adjacent structures (39).

**Powered Assisted Liposuction**

The notion of PAL was first introduced by Charles Gross, an American surgeon (40). The original motor design provided for a rotating blade within the cannula. Recently, several manufacturers have introduced systems that drive the cannula using a power source. These systems rely on electricity or are gas-driven. A small, variable-speed motor generates a reciprocating motion (forward and backward) in the cannula to produce a 2 mm to 4 mm excursion at the tip. The mechanism action is due to a jackhammer-type movement of the cannula tip which breaks up fat, and the fat aspirated

into the cannula openings is avulsed by the reciprocating motion. Fodor and Vogt (41) found that the two procedures were comparable with respect to complications, speed of recovery, and aesthetic results, and PAL was superior in terms of ease of fat removal. In addition, the aspirate from suction-assisted and power assisted lipoplasty are similar, and powered cannulas do not produce more bleeding than SAL when the tumescent technique is used (41, 42). According to Coleman (42), PAL has all the advantages and none of the disadvantages associated with iUAL. Vibration and noise are the only disadvantages of this technique. Scuderi *et al.* (43) compared iUAL, PAL and SAL. PAL is said to be a handy technique, with the most favourable cost-benefit ratio, and seems to be the best option for busy liposuction practices or fast office procedures.

### Vibroliposuction (VL)

Vibroliposuction represents a development of the PAL concept. In this system, the cannula is activated by air pressure, producing a complex movement of the tip. This movement, combining antero-posterior, supero-inferior and parasaggital displacement is called "nutation". The amplitude of this movement depends on the cannula length and diameter as well as the pressure entering the handpiece. A recent publication by Rebelo (44) describes this technique.

A study conducted in our department showed that vibroliposuction is more efficient than SAL. It removed 40% more fat than SAL under the same conditions. After centrifugation of the aspirated fat, the pure fat fraction was 70% greater than in the SAL.

The use of VL in our daily practice has shown that this procedure is safe. Complications were even fewer than with our previous use of SAL. We had no seromas and local hematomas were reduced. This technique is less traumatic because fat extraction is more efficient needing fewer passes of the cannula. VL respects the lymphatic vessels and neurovascular bundles. The combination of VL and open procedures showed the neurovascular structures to have been left intact, in the meshed tissue, and hematomas were fewer, compared with the previous combination with SAL.

In conclusion, this technique allows easier tissue penetration and causes less fatigue to the surgeon.

### Applications

Liposuction is not only an aesthetic tool. Non-cosmetic applications have continued to improve since the introduction of the technique. Although the most common use is lipoma removal, liposuction has also been used for benign symmetric lypomatosis, flap defatting, gynaecomastia, breast reduction, buffalo hump, hypertrophic insulin lipodystrophy, lymphedema and axillary hyperhidrosis (45).

It is also used in open procedures. As shown in the figure 4, removal of the fatty tissue around the neurovascular bundles creates a pseudo-plane facilitating tissue mobilisation with maximal safety. This allows improved healing and faster sensitivity recovery than with the usual undermining. This property, combining defatting and respect for the neurovascular structures, is used in abdominoplasty (46), bodylift (47), concentric medial thigh lift (48), breast reduction (49, 50) and brachioplasty (51, 51).

Extravasation injuries, which may induce important sequelae, can be managed by liposuction. Contrast solution or chemotherapeutic drugs in the subcutaneous tissue lead to necrosis and retraction. Performed immediately after the accident, soft tissue necrosis rarely occurs (53).

### Conclusion

Liposuction is currently the most frequently performed aesthetic operation in the world. Despite its widespread popularity, it must be practiced with maximum care and safety. Over time, many changes have taken place in the instrumentation and new techniques have been introduced. A number liposuction techniques are currently in use but our preference is for vibroliposuction. Fat extraction is easier, even in fibrous region or in secondary operations and the lymphatic and neurovascular structures encountered are respected. Thanks to the more efficient fat extraction, less cannula passes are necessary, reducing morbidity. Local traumas and surgeon fatigue are diminished. This results in safe, effective and precise surgery that can be used in any of the modern indications for liposuction, from precise and superficial aspiration in extravasation injury to massive fat aspiration in bodylifts.

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