British Journal of Plastic Surgery (2003), **56,** 266–271

doi:10.1016/S0007-1226(03)00112-7

BRITISH JOURNAL OF PLASTIC SURGERY

The effect of ultrasound-assisted liposuction and conventional liposuction on the perforator vessels in the lower abdominal wall

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SUMMARY. Scientific reports of clinical in vivo research into the effects and side-effects of ultrasonic-assisted liposuction (UAL) are scarce. Advocates of UAL claim that the damage to vascular and nervous structures is limited and even less than with conventional and/or tumescent liposuction (CL). The effect of tumescent infiltration alone and combined with either CL or UAL was assessed by performing injection studies of the panniculus adiposus of the lower abdominal wall of 20 fresh cadavers and five abdominoplasty specimens. Besides the control and infiltration groups ($n = 5$ in each), there was an additional group of ten cadaver flaps and five abdominoplasty flaps that underwent infiltration followed by UAL in the right half of the flap and infiltration followed by CL in the left half of the flap. Radiographs of these flaps were shown to a blinded panel of ten plastic surgeons, who were asked to evaluate and compare the damage on the basis of the number and magnitude of contrast-medium extravasations in the flap. Vascular damage to the perforating vessels was seen even after infiltration alone, although it was very limited. A variable amount of damage (ranging from little to extensive) was observed in the CL and UAL groups. Statistical analysis of the judgments of the observers could not show that either technique was less damaging than the other. UAL is, therefore, probably more beneficial to the surgeon than to the patient. The financial investment in the device is justified for surgeons with large liposuction practices, mainly, and probably solely, because of the reduced physical strain for the surgeon.

Keywords: liposuction, ultrasonic energy, vascularisation, injection study, perforator.

Liposuction is a frequently performed procedure in aesthetic surgery to improve the body contour.[1–3] Tumescent infiltration,[4,5] the use of blunt-tip cannulas and a more superficial approach[6] have led to better results over the last decade. In the late 1980s, Zocchi[7–11] added a new technique to the conventional liposuction by using ultrasonic energy to allow the selective destruction of adipose tissue. Ultrasonic energy is generated from electrical energy through a piezoelectric crystal. Applied to adipose tissue, this energy creates a cavitation phenomenon that causes the cellular destruction of the adipocytes. The tumescent fluid and the liquefied adipocytes form a stable fatty emulsion that can be extracted from the subcutaneous tissues by suction.

Meanwhile, several authors[12–15] have confirmed the benefits of ultrasonic-assisted liposuction (UAL). They report that UAL is less traumatic and causes little or no damage to the vascular, nervous and connective-tissue components, compared with conventional liposuction (CL). This argument was based on a few isolated reports of experimental research, and a limited amount of clinical data are presently available to support this theory.

The purpose of this clinical study was to evaluate and compare the vascular damage to the perforating vessels in the subcutaneous fat of the lower abdominal wall caused by UAL and CL.

Materials and methods

The lower abdominal walls of 20 fresh cadavers (less than 48 h post-mortem) were studied. None of them had undergone surgery in that region. An infra-umbilical ellipse (30 cm × 10 cm) centred over the midline was marked on the skin. A median line divided the flap into two equal halves. Next, infra-umbilical and suprapubic median stab incisions were made (Fig. 1(A)). Before harvesting, these flaps were divided into three groups and underwent the following manipulations, which were approved by the Ethical Commission of the University Hospital of Gent.

Group 1: UAL versus control

Five flaps were subjected to infiltration followed by UAL in the right half of the flap. UAL was performed with the Lysonix 2000 Ultrasonic System and a 4 mm hollow titanium cannula. UAL was combined with 0.4 bar negative pressure. During the evacuation phase immediately following the UAL, the remaining emulsion was removed

Presented at the 12th Congress of the International Confederation for Plastic, Reconstructive and Aesthetic Surgery, 27 June–2 July 1999, San Francisco, CA, USA.

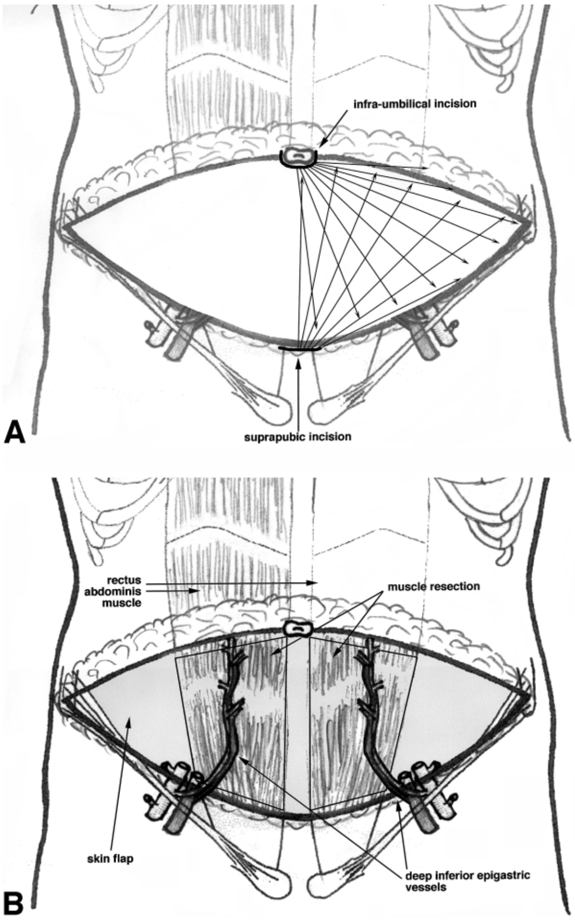

Figure 1—(A) Schematic drawing of the surgical procedure showing the position of the stab incisions. The cannula was moved radially through both incisions so that the subcutaneous tunnels intersected in a criss-cross fashion. (B) Schematic drawing indicating the amount of skin, fat and muscle resected from the lower abdominal wall, including the deep inferior epigastric vessels through which the Microfil was injected.

from the subcutaneous tissues by CL with a 3 mm Mercedes cannula at a negative pressure of 0.4 bar. The duration of liposuction is shown in Table 1. Infiltration was performed by injecting 200–600 ml of Klein's solution into the subcutaneous fat of the flap, until a tumescent state was reached. In the left side no infiltration or liposuction was performed. The blood vessels of the left half of each flap were left untouched and represent the control group.

Table 1 The operative techniques applied to each half of each flap. The durations of ultrasound-assisted liposuction (UAL) combined with the evacuation phase (1 min) and conventional liposuction (CL) are marked for both the umbilical and the pubic incisions. The total liposuction time was always 6 min

Group	Side of flap	*n*	Infiltration	Operation	Umbilical time (*min*)	Pubic time (*min*)
1	left	5	no	–	–	–
	right	5	yes	UAL	2 + 1	2 + 1
2	left	5	yes	–	–	–
	right	5	yes	UAL	2 + 1	2 + 1
3	left	10	yes	CL	3	3
	right	10	yes	UAL	2 + 1	2 + 1
4	left	5	yes	CL	3	3
	right	5	yes	UAL	2 + 1	2 + 1

Group 2: UAL versus infiltration

Five flaps were subjected to infiltration followed by UAL in the right half of the flap and infiltration only in the left half of the flap. In this way, the effect on the vascular structures of infiltration alone could be compared with that of infiltration and UAL. UAL and infiltration were performed as described above. The duration of liposuction is shown in Table 1.

Group 3: UAL versus CL

Ten flaps were subjected to infiltration followed by UAL in the right half of the flap and infiltration followed by CL in the left half of the flap. UAL and infiltration were performed as described above. CL was performed with a 3 mm Mercedes cannula and a negative pressure of 1.0 bar. The duration of liposuction is shown in Table 1. This group was used to compare directly the vascular damage caused by the two liposuction techniques.

Group 4: UAL versus CL in abdominoplasty specimens

The same procedure as in Group 3 was followed for five abdominoplasty specimens before removing the skin and fat from the lower abdominal wall.

Both UAL and CL of the flap were performed both superficial and deep to Scarpa's fascia. The level of liposuction relative to Scarpa's fascia was checked with sagittal radiograms of the specimens after vascular injection. The cannula was moved radially through both incisions so that the subcutaneous tunnels intersected in a criss-cross fashion (Fig. 1(A)).

After liposuction was performed, the skin island with its subcutaneous fat was incised and harvested together with the underlying anterior rectus fascia, both rectus abdominis muscles and the deep inferior epigastric vessels (Fig. 1(B)). Both deep inferior epigastric arteries in flaps from Groups 1, 2 and 3 were injected with 10 ml radio-opaque Microfil (Flow Tech Inc., Boulder, CO, USA) at a constant pressure, immediately after harvesting the flap. Radiograms were taken after removing the muscle and skin.

To assess the severity of damage to the perforating vessels caused by CL and UAL, the radiographs of flaps from Groups 3 and 4 were shown to a blinded panel of ten plastic surgeons. Images were inverted at random to avoid biased answers. The panellists were asked to evaluate and compare the damage to each half of the flap on the basis of the number and magnitude of Microfil extravasations. Each panellist scored each half as no, little, fair or extensive vessel damage, with a score of 1, 2, 3 or 4, respectively. Additionally, they were asked to compare the two halves and indicate the half that, in their opinion, had the most vessel damage. The individual scores were statistically analysed by determining the kappa coefficient. This coefficient represents the correlation of two observers, in which 0 is no agreement and 1 is perfect correlation.

Informed consent was obtained from all abdominoplasty patients. Approval for the cadaver dissections and harvesting of the abdominoplasty specimens was obtained from the Ethics Commission of the University Hospital Gent and the National Ethics Council.

Results

Sagittal radiographs confirmed that UAL and CL were performed superficial and deep to Scarpa's fascia in all flaps.

In all flaps of Group 1, an intact arterial system was seen in the left half of the flap. In the right half, there was a variable amount of extravasation, representing vascular damage ranging from fair to extensive (Fig. 2).

In Group 2, the left side of the flap (infiltrated only) showed a few pinpoint extravasations, but the arterial system was intact. The right half, on the other hand, once again showed vascular damage ranging from little to extensive (Fig. 3).

In Groups 3 (Figs 4 and 5) and 4 (Fig. 6) vascular damage varied from little (score 2) to extensive (score 4). In no case was no vascular damage seen. The mean scores given by the panellists for each of the 10 flaps are shown in Table 2. Among the observers a high degree of unanimity was recorded: the scoring of each observer did not differ by more than one point from the remaining observers for every half of every flap. Perfect unanimity was observed in two left halves (specimens 6 and 10 of Group 3) and one right half (specimen 6 of Group 3).

On the question of which half was the more damaged, a unanimous answer was given for six specimens (specimens 1, 4, 7 and 10 of Group 3, and 1 and 2 of Group 4). A near-unanimous answer (just one answer different) was given for specimens 2 and 6 of Group 3 and specimen 4 of Group 4. In five specimens (specimens 3, 8 and 9 of Group 3, and 3 and 5 of Group 4) three answers were opposed to seven, and in specimen 5 of Group 3, four answers were opposed to six. Of the specimens with unanimous or near-unanimous answers, five were judged to have the most vascular damage on the left side, treated with CL, and four on the right side, treated with UAL. In six other specimens no unanimity was reached (Tables 2 and 3).

Discussion

Over the last few years, several authors have recommended UAL because of a number of advantages this technique has over CL. Proponents of UAL report that the specificity of ultrasonic sound waves means that they selectively target fat cells. Damage to connective tissue and neurovascular structures is said to be minimal.[9–15] It has also been stated that large volumes of fat can be effectively removed with minimal blood loss, little or no bruising and excellent control of body contour with better skin retraction. Fibrous difficult-to-treat areas, such as the back, the male breast and secondary cases, are easily treated with UAL. The procedure is also less physically demanding for the surgeon than CL.[12–15] Although it is very difficult to measure or calculate the difference in force that the surgeon needs to apply to a CL cannula and a UAL probe, it is clear to anyone who has used the UAL probe that movements are less strenuous.

However, other authors have been unable to prove the superiority of UAL over CL in terms of safety, efficacy and final results, and have stated that UAL and CL are complementary, enhancing cosmetic results.[16–18] Short-term side-effects, such as burns, infections, fibrosis, seromas and skin necrosis, have been reported.[12,18–20] Long-term complications[21,22] may theoretically arise from three aspects of ultrasonic-energy production: first, sonoluminescence, or the conversion of sound into light, which may produce ultraviolet and possibly soft X-ray radiation; second, sonochemistry, or the production of a

Figure 2—Representative negative radiograph of a flap from Group 1. The left side did not receive any treatment. The right side received infiltration and ultrasound-assisted liposuction. The severity of extravasation in the right side was judged as 'fair'.

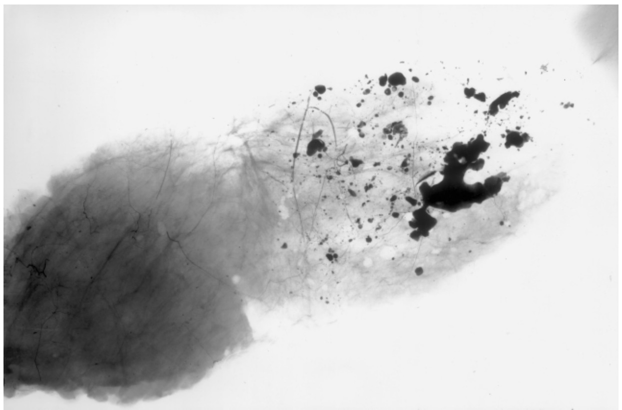

Figure 3—Representative negative radiograph of a flap from Group 2. The left side received infiltration only. The right side received infiltration and ultrasound-assisted liposuction. The severity of extravasation in the left side was judged as 'little' and in the right side as 'extensive'.

Figure 4—Representative negative radiograph of a flap from Group 3, showing more vascular damage in the half that received infiltration and ultrasound-assisted liposuction (right side). The left side received infiltration and conventional liposuction. The severity of extravasation in the left side was judged as 'fair' and in the right side as 'extensive'.

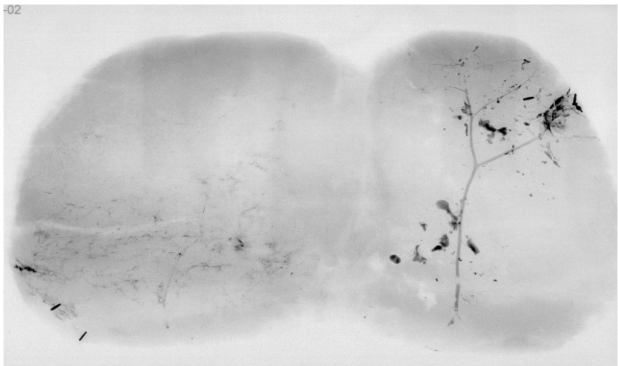

Figure 6—Representative negative radiograph of a flap from Group 4, showing comparable vascular damage in the right half, which received infiltration and conventional liposuction, owing to the larger extravasations, and the left half, which received infiltration and ultrasound-assisted liposuction, owing to a higher number of extravasations. The severity of extravasation in both halves was judged as 'fair'.

variety of free-radical by-products as a result of the rupture of molecular chemical bonds caused by the high temperatures generated by the implosion of fat cells; and third, the thermal effect on deep soft-tissues. Although the thermal effect leads to fibrosis and tightening of the skin, which is positive for the aesthetic result, a Marjolin ulcer, as seen in deep burns, could be a possible complication.

At the moment, it is difficult to estimate the long-term impact of these phenomena on the fat tissue. Therefore, it would probably be safer to avoid using UAL in oncological risk areas, such as the breast, and to await further research results. Until the last decade, ultrasound technology was used only for diagnostic and therapeutic purposes, employing an energy range of up to $1-3\ \mathrm{W\,cm^{-2}}$. UAL uses energy levels 30–50 times higher. Applying energy induced by ultrasound waves at this level carries the risk of provoking unforeseen side-effects.[22]

Some studies, using histological[24] and microangiographic[25] examination, have reported that the perforator vessels remain intact following liposuction. Another study, investigating CL, found no vessel damage in patients undergoing liposuction using endoscopy.[26] On the other hand, in an experimental study using a rat model, it has been shown that there is an increased possibility of necrosis in skin flaps raised from regions where CL has previously been performed.[27] A clinical study using Doppler ultrasonography to examine perforator vessels in patients showed that 50% of the perforators could not be detected after CL. The vacuum used in liposuction is mainly responsible for this damage.[28]

Kenkel et al compared the effects of UAL and CL on tissue in eight pigs.[23] They concluded that there was less blood loss if UAL was applied. From their study it was not clear whether this was due to the UAL or to the fact that the CL side was not infiltrated. It was also concluded that vascular structures were better preserved with UAL.

This study reports, for the first time, a comparison of the vascular damage caused by UAL and CL in a selective area in fresh human cadavers. By showing the

Figure 5—Representative negative radiograph of a flap from Group 3, showing more vascular damage in the half that received infiltration and conventional liposuction (left side) owing to a higher number of extravasations. The right side received infiltration and ultrasound-assisted liposuction. The severity of extravasation in both halves was judged as 'extensive'.

Table 2 The observers' mean scores of vascular damage for each half of each of the ten flaps in Group 3. The last column is the observers' opinion of which side showed the most vascular damage in cases where this was unanimous or near-unanimous (in specimens 2 and 6, only one observer disagreed)—no unanimity was reached

Specimen	Observers' mean score of left half (CL)	Observers' mean score of right half (UAL)	Judged as most damaged
1	2.2	3.6	right
2	3.5	3.2	left
3	3.3	3.6	–
4	1.9	3.4	right
5	3.5	3.4	–
6	4.0	4.0	left
7	3.5	2.6	left
8	2.6	2.7	–
9	2.3	2.2	–
10	4.0	2.5	left

Table 3 The observers' mean scores of vascular damage for each half of each of the five flaps in Group 4. The last column is the observers' opinion of which side showed the most vascular damage in cases where this was unanimous or near unanimous—no unanimity was reached

Specimen	Observers' mean score of left half (CL)	Observers' mean score of right half (UAL)	Judged as most damaged
1	2.2	3.6	right
2	3.5	3.2	left
3	3.3	3.6	–
4	1.9	3.4	right
5	3.5	3.4	–

images of specimens treated with UAL on one side and CL on the other to a blinded panel of experienced plastic surgeons, we found that there was no clear conclusion that UAL causes less vascular damage. The judgement of the observers was felt to be reliable because of the high Kappa coefficient when judging the severity of the vascular damage on each side.

Therefore, in humans, a comparable amount of damage to the subdermal plexus and the myocutaneous and septocutaneous perforator vessels is probably caused by tumescent CL and UAL. A possible criticism of this study model could be that vasospasm, which will occur in vivo, does not take place in a cadaver. Therefore, we also performed UAL and CL in five patients before they underwent abdominoplasty. Their skin flaps showed, after infiltration, skin removal and X-ray reconstruction, the same pattern as the cadaver skin flaps. Also, vasospasm in vivo will not prevent the damage caused by UAL or CL.

Significant damage to vascular structures during UAL is probably inevitable. Even if the ultrasonic movement of the probe does not cause any damage, the gross movements of the cannula through the tissues will damage the vessels in the same way as CL. Also, the evacuation phase following UAL will damage the vessels. Even infiltration (Group 2) can cause vascular damage, without any liposuction being performed.

The neural damage that UAL can cause,[28] the possible short- and long-term complications and the similar level of vascular damage, make the choice of UAL over CL not so clear-cut as previously reported. Certainly, its ease of use and the less-tiring manipulation are undeniable advantages of this device. One should consider, nevertheless, whether the considerable financial investment outweighs this benefit. This will, of course, depend on how frequently the UAL device is used in the surgeon's practice. The strong financial interests of certain companies in this equipment and the lack of sufficient scientific data on vascular damage and long-term results make it difficult for a number of colleagues to make an objective choice. The commercial advertising of this technique by some non-plastic-surgeons or even non-physicians has created a new group of patients who demand UAL thinking that it is the only good treatment. This commercial pressure benefits the manufacturer of the device but does not always further the well-being of our patients.

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Paper received 1 October 1999.
Accepted 5 February 2003.