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New Waves for Fat Reduction: High-Intensity Focused Ultrasound

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With the rising demand for body contouring, noninvasive devices for fat reduction have become increasingly popular and have grown dramatically over the past decade. High-intensity focused ultrasound (HIFU) has been used for nearly half a century for the noninvasive treatment of tumors of various organs, but has only recently been evaluated as a method for the selective destruction of adipose tissue. HIFU works by ablating subcutaneous adipose tissue and causing molecular vibrations that increase the temperature of local tissue and induce rapid cell necrosis. Several studies reveal the safety and efficacy of HIFU for fat reduction in the abdomen and the flanks. These studies indicate consistent reduction in abdominal circumference >2 cm after a single treatment. The adverse events are limited to transient tenderness, bruising, and edema. Increased utility of HIFU for fat reduction will likely increase over time.
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With the rising demand for body contouring, noninvasive devices for fat reduction have become increasingly popular and have grown dramatically over the past decade. Body contouring refers to the optimization of the definition, smoothness, and shape of the human physique.[1] Historically, the approach to body contouring has largely involved invasive procedures such as liposuction and abdominoplasty. Liposuction is among the most popular of cosmetic surgery procedures performed in the United States, but it is an invasive procedure with attendant downtime and potential rare but significant risks, including complications from anesthesia, infections, and even death.

In recent years, increasing numbers of nonobese patients have been looking for procedures with minimal downtime that are associated with little or no risk, even if they are aware that such procedures are not as effective and may require repeated treatments compared with more traditional surgical approaches. Current nonsurgical body contouring devices, including cryolipolysis,[2] low-level laser therapy,[3] low-energy nonthermal ultrasound,[4] and high-intensity focused ultrasound (HIFU),[5] have become popular as noninvasive methods for body contouring and fat reduction.

Liposonix (Solta Medical, Inc, Hayward, CA) uses HIFU that is designed to induce stable cavitation and disrupt fat cells.[6,7] HIFU has been used for nearly half a century for the noninvasive treatment of tumors of various organs, but has only recently been evaluated as a method for the selective destruction of adipose tissue. HIFU works by ablating subcutaneous adipose tissue (SAT) and causing molecular vibrations that increase the temperature of local tissue and induce rapid cell necrosis. The temperature quickly reaches >56°C, resulting in coagulative necrosis of the adipocytes and subsequent reduction of the fat layer. The intensity levels above and below the focal zone remain relatively low. At high frequencies (2 MHz), ultrasound energy is highly convergent, such that tissue damage is confined to a small focal volume.[8] After the treated adipose tissue has been thermally coagulated and destroyed, chemotactic signals activate the body's normal inflammatory response mechanisms. Macrophages are attracted to the treated area where they engulf and transport the lipids and cellular debris.[6] The lipids released from disrupted adipose tissue are ultimately metabolized, and the lesion gradually heals in a normal fashion. This results in a

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volumetric collapse of the treated tissues and an overall reduction in local adipose tissue volume.[6]

Pilot Studies

In an early trial, Garcia-Murray et al studied 19 healthy female subjects who were scheduled to undergo elective abdominoplasty.[9] The patients were treated with 1 of 5 different HIFU energy levels or 2 treatments using 1-2 HIFU energy levels performed 4 weeks apart. Patients were evaluated after 1, 2, 3, 4, 7, 28, and 56 days. Abdominoplasty was performed 1-18 weeks after treatment. The histologic examination of excised tissue showed well-demarcated adipocyte disruption. A normal inflammatory response with the presence of macrophages was observed, and phagocytosis of released lipids occurred after 14-28 days. The adverse effects included swelling, ecchymosis, dysesthesia, and pain on treatment.

Gadsen et al reported 3 studies that investigated the use of the HIFU in human patients.[10] All 3 studies enrolled healthy adult men and women who had a body mass index (BMI) <30 and at least 2.0 cm of fat at each intended treatment site. The thickness of the SAT in the treated area was determined by a manual pinch test during physical examination. A total of 152 patients were treated with total HIFU energy doses of 47-331 J/cm^2. This study included patients who presented for elective abdominoplasty and underwent HIFU treatment to those areas. For these patients, abdominoplasty was performed up to 14 weeks after the HIFU procedure.[10]

Post-treatment ultrasonography confirmed that the HIFU effects were limited to targeted SAT layers. The histopathology revealed well-demarcated disruption of adipocytes within the targeted SAT. The lesions were limited to the target area, without evidence of thermal injury to the dermis or the epidermis. Phagocytosis of released lipids and cellular debris occurred between days 14 and 28, and the phagocytized lipids underwent normal hepatic metabolism. The healing progressed normally and was 95% complete after 8-14 weeks. Serum lipids were measured over 4 weeks and did not demonstrate any clinically significant changes in the serum levels of free fatty acids, cholesterol, or triglycerides. The adverse events were temporary treatment discomfort, edema, erythema, dysesthesia, and ecchymosis. There were no serious device-related adverse events.[10]

Early Studies

Fatemi reported treatments in the largest group to date to receive treatment with HIFU.[6] A total of 282 patients with a mean age of 41.3 years underwent a single HIFU treatment, which included areas of the anterior abdomen and flanks. The patients had a minimum of 1.5 cm of adipose tissue beyond the planned HIFU focal depth. A group of patients in the study underwent elective abdominoplasty in the treated area, and the histopathology was examined. The HIFU device was calibrated to deliver a total energy ranging from approximately 140 J/cm^2 or higher and to reach a focal depth of 1.1-1.8 cm. The mean energy dose was 137 J/cm^2, which was divided in 2 passes and 2 different focal depths, and there was a mean waist circumference reduction of 4.7 cm noted 3 months after the treatment. Patients treated with a total energy >133 J/cm^2 achieved an average waist reduction of 4.6 cm compared with the average waist reduction of 4.2 cm achieved by patients treated with a total energy <126 J/cm^2. The abdominoplasty tissues revealed well-defined impact zones in gross pathology. The lesions had a safe and consistent distance from the epidermis and dermis. The higher energy levels did produce larger lesions.[6]

In this study, 38 patients (13.5%) reported 1 or more adverse events, including prolonged tenderness after treatment (3.5%), edema (2.1%), hard lumps (1.1%), significant ecchymosis (9.9%), and significant pain during treatment (2.8%). The hard lumps, tenderness, and ecchymosis resolved in <4 weeks, and edema resolved in <12 weeks. All the adverse events were temporary, and there was no evidence to suggest these adverse events were dose-related.[6]

Fatemi and Kane reported the results of a retrospective review of 85 patients who underwent HIFU for treatment of excess adipose tissue of the anterior abdomen and flank. The mean age was 43.8 years, and each patient received a single treatment. The mean energy level was 134.8 J/cm^2 and a focal depth of 1.1-1.6 cm. There was an average 4.6-cm reduction in waist circumference. Of the 85 patients, 10 (11.8%) reported adverse events, including prolonged tenderness, ecchymosis, hard lumps, edema, and pain, which resolved spontaneously.[11]

Figure 1 Image of the Liposonix Model 2 System (Solta Medical, Hayward, CA).

Figure 2 Image of the handpiece for the Liposonix Model 2 System (Solta Medical, Hayward, CA).

Recent Studies

Solish et al studied the effects of different energy levels on fat reduction using HIFU in a randomized single-blinded postmarketing study.[12] There were 47 patients who had HIFU treatment on only the anterior abdomen at energy levels of 47, 52, or 59 J/cm^2; each was applied in 3 passes at graduated depths. The mean age was 42-44 years for each group, and most patients were female (86%-94%) and white (79%-93%). The waist circumference was measured at baseline, after treatment on day 0, and at follow-up visits in 3 zones: the level of the iliac crest, 2 cm above the umbilicus, and 2 cm below the umbilicus. At the 12-week follow-up visit, there was an average abdominal circumference reduction of 2.51 cm. Of note, this reflects only treatment of the abdomen and not the flanks.

Most patients (90%) received analgesic premedication with an opioid and experienced minimal to mild discomfort during the study. The patients treated at 59 J/cm^2 experienced the greatest discomfort. However, an energy level of 59 J/cm^2, administered in 3 passes for a total energy dose of 177 J/cm^2, provided the most rapid results with the greatest reduction in waist circumference after 4 weeks. Adverse events included mild and transient abdominal tenderness and bruising in a majority of the patients. The limitations of this study include lack of longer follow-up past 12 weeks and also lack of a control group for comparison.

Table 1 Optimal Treatment Areas for HIFU

Optimal Treatment Areas:
Abdomen: upper and lower
Flanks

Table 2 Optimal Patient Selection

Optimal Patient Selection
BMI < 30
At least 2.5 cm of fat (able to "pinch at least an inch")
Good skin tone (no folds in the treatment area)
No scars in the treatment area
No hernias in the treatment area

Jewell et al reported the results of a randomized, sham-controlled, single-blinded trial evaluating the efficacy through 12 weeks and safety through 24 weeks after HIFU treatment.[5,13] In this study, 180 patients were treated at 9 clinical sites in the United States. These patients were randomized to 3 treatment groups (3 passes per patient): 47 J/cm^2 (141 J/cm^2 total), 59 J/cm^2 (177 J/cm^2 total), or 0 J/cm^2 (no energy applied; sham control). The anterior abdomen and flanks were treated. The mean age range was 41.1-42.8 years, and the average BMI was 25.2. Of the 180 subjects, 85% were female, 15% were male, 87% were Caucasian, and 13% were non-Caucasian. At each visit (screening, treatment day, posttreatment weeks 4, 12, and 24), the treatment area was examined, waist circumference was measured, and diagnostic ultrasonography of the treatment area was performed. Blood samples were obtained at baseline, within 1 hour after treatment, and at each follow-up visit. The blood samples were used to analyze the lipid panel, inflammatory markers, coagulation, and renal function.

The adverse events included mild to moderate discomfort, ecchymosis, and edema, all of which were transient and did not persist past 16 days. There were no reports of scarring or burns. Diagnostic ultrasonography showed no abnormalities in the treated areas at any visit. There were no clinically meaningful changes in lipid panel findings, inflammatory markers, or renal or hepatic function.

Most recently, data from a postmarketing evaluation were collected using the Model 2 System (Figs. 1 and 2) from 22 sites, including up to 10 patients at each site, with 132 patients in total. The treated patients had a BMI <30 and had at least 2.5 cm of fat in the abdomen and flanks at baseline. Tables 1 and 2 describe the optimal treatment sites and patient selection. Treatments typically started at an energy level between 40 and 50 J/cm^2, with energy increased or decreased based on patient tolerance. The total fluence at the end of treatment ranged between 140 and 180 J/cm^2. All patients were seen at 4-, 8-, and 12-week follow-up visits, at which the waist circumference and weight were measured. Standardized photographs were taken at those visits.

After 12 weeks, there was an average weight loss of 0.74 lbs, and the average reduction in waist circumference was 2.55 cm (n = 42). Figures 3-6 depict pretreatment and posttreatment results in 2 patients. Although the data are impressive, the photographs only appear modest. New techniques are being studied to enhance the effects of HIFU, including pulse stacking and using higher energy levels. Pain manage-

Figure 3 Before treatment with high-intensity focused ultrasound (HIFU). Courtesy of Anne Chapas, MD.

Figure 4 Eight weeks after treatment with HIFU. This patient had a 5.9-cm reduction in her waist. Courtesy of Anne Chapas, MD.

Figure 5 Before treatment with HIFU. Courtesy of Solta Medical Aesthetic Center.

ment was not required, but clinicians used a variety of medications, including acetaminophen with oxycodone, acetaminophen with hydrocodone, tramadol, acetaminophen, ibuprofen, and intramuscular ketorolac. The procedures were well tolerated, and the patients were satisfied to very satisfied with the treatment. Adverse events included ecchymosis lasting up to 2 weeks, superficial tenderness that resolved over a few weeks, and transient edema lasting for 2-3 days.

Figure 6 Eight weeks after treatment with HIFU. Courtesy of Solta Medical Aesthetic Center.

Conclusions

HIFU is a new promising method for fat reduction. HIFU works by ablating SAT and causing molecular vibrations that increase the temperature of local tissue and induce rapid cell necrosis. Several studies reveal the safety and efficacy of HIFU for fat reduction in the abdomen and the flanks. These studies indicate consistent reduction in abdominal circumference >2 cm after a single treatment. The adverse events are limited to transient tenderness, bruising, and edema. As a result, the likelihood of using HIFU for fat reduction will increase over time.

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