

Body Sculpting Techniques: Noninvasive High-Intensity-Focused Ultrasound Innovation in Fat Removal

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ABSTRACT

Liposuction is among the most common cosmetic surgical procedures performed for body sculpting. Newer techniques such as ultrasound-assisted liposuction, power-assisted liposuction, laser-assisted liposuction, and noninvasive approaches such as mesotherapy, cryolipolysis and high-intensity-focused ultrasound (HIFU), have the potential to improve efficiency, minimize adverse consequences, and shorten postoperative recovery time. The HIFU in particular reduces treatment time, reduces scarring, and ameliorates the risk of severe posttreatment complications such as infection that are associated with surgical procedures. HIFU also eliminates the necessity for general anesthesia and the associated risks. HIFU thus allows patients to return quickly to activities of daily living with minimal downtime as compared to traditional surgical liposuction procedures. For these reasons, noninvasive methods like HIFU are increasingly preferred by patients who are resistant to the invasive surgery involved in conventional liposuction procedures.

Keywords: body sculpting, noninvasive, liposuction, high-intensity ultrasound

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Liposuction or lipoplasty is among the most common cosmetic surgical procedures performed for body sculpting. Data from the American Society for Aesthetic Plastic Surgery indicates that liposuction ranked second among all invasive cosmetic procedures in 2009, with 283 735 procedures performed.¹ A US-based survey of patients who had undergone liposuction surgery determined that although 80% of patients reported satisfaction with their procedure, weight gain occurred in 43%; fat return, particularly in the abdomen, was reported by 65%; and most patients (75%) reported mild to moderate discomfort, with 40% reporting discomfort lasting more than 7 days.² Conventional suction-assisted liposuction under tumescent anesthesia remains the most common approach; however, with recent advances in technology several newer invasive and noninvasive techniques have been developed that have the potential to improve efficiency, minimize adverse consequences, shorten postoperative recovery time, and enhance ease of the surgical process.^{3,4}

CANDIDATES FOR BODY SCULPTING

A preoperative evaluation comprising a detailed medical history, physical examination, and appropriate laboratory work is essential to ensure optimal candidate selection. Common concerns include past history of bleeding disorders, thrombophlebitis, diabetes, or other surgical risks, massive weight loss, previous surgery or liposuction in the past, the presence of an implantable electrical device and neurosurgical

cerebrospinal shunt, and cancer. Before liposuction is undertaken, the patient should also be screened for cardiovascular and blood pressure disorders and deemed medically fit to undergo anesthesia and/or a surgical procedure.⁵⁻⁷

A detailed medication review including herbal remedies, vitamin supplements, aspirin, and oral contraceptives should be undertaken to identify all potential causes of bleeding, hypercoagulability, or drug-drug interactions. It is preferable to discontinue all drugs 3-4 weeks prior to the procedure following consultation with the patient's primary physician.^{5,6,8,9}

A systematic physical examination should be performed with particular focus on hernias, scars, asymmetries, cellulite, and stretch marks in the area of concern. Key criteria to evaluate include quality and elasticity of skin, presence of striae, dimpling or cellulite, areas of lipodystrophy, contour deformities, and asymmetries. The underlying musculofascial support and zones of adherence should also be ascertained. Moreover, the patients should have a BMI of ≤ 30 , and should not have extensive, nonlocalized fat. Additionally, patients must have at least 1 cm of adipose tissue thickness beyond the selected area to be treated.^{5,6}

Prior to the procedure the physician should also have a detailed discussion to evaluate the patient's motives, expectations, and ensure that realistic goals are set. In addition to a successful procedure, adoption of positive lifestyle changes including exercise and proper diet are essential to achieve successful long-term outcomes, and patients who embrace

diet, exercise, and a healthy lifestyle are much more likely to lose weight and be satisfied with the results of liposuction. Finally, it is essential to obtain documented informed consent from the patient before the surgery; in addition, pre- and postprocedure photo documentation is recommended.^{5,6,10}

LIPOSUCTION TECHNIQUES

Tumescent liposuction

Tumescent local anesthesia (TLA) has been a dominant method of liposuction over the past two decades. It involves infiltration of large volumes of dilute local anesthetic prior to suction and has been found to facilitate lipocontouring by significantly reducing blood and intravascular fluid loss.⁵

In recent years, several innovative techniques have evolved to improve outcomes. These include ultrasound-assisted liposuction; power-assisted liposuction; laser-assisted liposuction; all used in combination with TLA; and noninvasive approaches such as mesotherapy, cryolipolysis, and high-intensity-focused ultrasound (HIFU).

Power-assisted liposuction

In power-assisted liposuction, an external power source drives the liposuction device, which consists of a vibrating cannula with or without an oscillating blade within cannulas of variable sizes, to facilitate the removal of fat. Powered liposuction has been found to improve the efficacy of subcutaneous fat removal during liposuction by reducing procedure times, intraoperative pain, and surgeon fatigue, while increasing the amount of fat aspirated per minute. In addition, power-assisted liposuction reduces postoperative pain, ecchymoses, and edema leading to faster recovery time and higher patient satisfaction than conventional manual liposuction.^{6,11-13}

Ultrasound-assisted liposuction

Ultrasound-assisted liposuction utilizes an ultrasound to breakdown fat by mechanical, cavitation, and thermal effects. The emulsified fat is then removed through the conventional liposuction cannula. Ultrasound-assisted liposuction is useful in removing fat from fibrous areas with less surgeon fatigue, but the major drawback is the associated risk of thermal injury to surrounding tissues. The procedure also requires larger incisions and longer operative times.⁶ Lawrence and Cox compared the efficacy of application of high-intensity continuous wave ultrasound to the placebo effect of extremely low-intensity ultrasound prior to tumescent liposuction and concluded that there is no advantage with the application of external ultrasound prior to liposuction.¹⁴

Laser-assisted liposuction

Laser-assisted liposuction involves the insertion of a laser fiber through a small skin incision and application of energy to disrupt fat cell membranes and emulsify fat as well as breaking down fibrous components of the subcutaneous

tissue structure. A conventional liposuction cannula is then used for fat evacuation. Laser-assisted liposuction is believed to induce skin tightening by stimulating collagen formation in the treated areas, thereby improving skin elasticity and enhancing skin contraction. In addition, being a minimally invasive procedure it allows for a shorter recovery time.^{4,15} However, in an evaluation of laser-assisted liposuction versus suction-assisted liposuction by Prado and coworkers, there was no substantial difference in cosmetic outcomes; and although early postoperative pain was less with the laser-assisted procedure, the operative time was longer in the laser-assisted procedure.¹⁶ A particular concern was that elevated free fatty acid/triglyceride levels in the aspirate following laser treatment suggested that subdermal heating may have caused skin injury.^{16,17}

NONSURGICAL ALTERNATIVES TO LIPOSUCTION

Mesotherapy

Mesotherapy is a new alternative method for body contouring, in which agents are injected to reduce fat by dissolving fat deposits. The noninvasive nature of the procedure is an appealing option for patients; however, the safety, efficacy, and mechanism of action of mesotherapy have yet to be adequately evaluated. To date, there are no standardized protocols that can predict the amount of fat that will be dissolved with a defined dosage of a specific treatment agent.¹⁸ Park and coworkers evaluated the efficacy of mesotherapy for body contouring in 20 women, who were injected a mixed solution containing aminophylline, buflomedil, and lidocaine into the superficial dermis of the medial aspect of one thigh every week using a mechanical delivery gun, while the other thigh received no treatment. At the end of 12 weeks of treatment, there was no significant difference in thigh girth, cross-sectional area, or thickness of the fat layer between the treated and untreated thigh. Moreover, patients treated with the method reported poor satisfaction.¹⁹

Lipodissolve, a variant of mesotherapy involves the injection of a standardized solution into the subcutaneous fat to reduce localized fat deposits, cellulite, or postlipoplasty deformities. Hyperpigmentation and persistent pain are among the side effects commonly associated with this procedure; in addition, suboptimal outcomes have frequently been reported.^{20,21} While mesotherapy offers the advantages of a minimally invasive procedure, robust clinical evidence regarding the safety and efficacy of the procedure is required before mesotherapy gains wider acceptance.

Cryolipolysis

Cryolipolysis is a noninvasive method that involves the use of controlled localized heat extraction (cooling) to reduce fat cells. This procedure delivers intensive cooling to the subcutaneous fat, resulting in apoptosis of adipocytes. Adipocytes are more easily damaged by cold temperatures than epidermal cells. The damaged adipocytes are gradually removed from the

body over a period of 2–4 months. As a result, 2–4 months may be required for clinical effects to be realized.²² However, the exact mechanism of action for cryolipolysis is not yet completely understood.²³ In clinical trials cryolipolysis, over 2 months, resulted in substantial fat reduction without damage to the skin.²⁴ Erythema of the skin, bruising, and temporary numbness at the treatment site are the commonly observed side effects, however these mostly resolve over time.²⁵

High-intensity-focused ultrasound (HIFU)

A nonsurgical method of body contouring that involves the use of high-HIFU for thermocoagulation-mediated fat removal. The HIFU uses the same energy source as a diagnostic ultrasound and relies on the same principles. Ultrasound propagates harmlessly through tissue, but if the ultrasound beam carries sufficient energy and is focused, it can cause a local rise in temperature to cause necrosis of tissue.²⁶ HIFU can be focused at specific depths in subcutaneous adipose tissue, preventing exposure and damage to tissues outside of the focal zone. The intensity is brought to a sharp focus in the subcutaneous fat to destroy adipocytes. Lesion healing and lipid resorption follow normal healing processes with the gradual metabolism of free lipids.²⁷

The HIFU technology is a thermomechanical process that works in two ways. First, it disrupts the cell membrane due to its mechanical effect. Second, the heat generated in the focal zone results in temperatures above 58°C, at which coagulative necrosis of fat cells in the area occurs; the surrounding tissues are not affected. The dead cells then trigger a wound-healing response that recruits macrophages and other cells to the area and clears lipids and the cellular debris of the destroyed adipocytes, resulting in a reduction in local fat stores. As a consequence of the wound-healing response, inflammatory cells and fibroblasts attracted to the area in conjunction with the denaturing of collagen by the heat results in the thickening and shortening of collagen fibers and contraction.²⁸ Most of the cellular debris and lipid is removed within 12 weeks of the procedure, with 95% removed within 18 weeks. This removal process is not associated with any significant impact on plasma lipid levels.^{6,29}

During the HIFU procedure, patients may experience a localized prickling or tingling sensation, warmth, heat, discomfort, or pain. Side effects after the procedure include temporary erythema, ecchymosis, discomfort, paresthesia, and edema. However, these side effects are mild in intensity, temporary, and resolve within a few weeks.^{6,29}

Analysis of data from 282 patients who underwent a single HIFU treatment of the abdomen and flanks with a mean energy dose of 137 J/cm² divided into two passes and two different focal depths, revealed that the single treatment that took approximately 45–60 min to complete resulted in an average 4.7 cm reduction in waist circumference after 3 months. Major treatment related side effects included significant ecchymosis (*n* = 28), prolonged tenderness after treatment (*n* = 10), edema (*n* = 6), and hard lumps (*n* = 3). However, none of these

adverse events were serious and all were temporary resolving within 12 weeks. Importantly, 70% of patients were satisfied with the reduction in circumference achieved by the procedure at 3 months.²⁹

Nonthermal-focused ultrasound

In addition to HIFU-induced thermocoagulation-mediated fat removal, nonthermal, ultrasonic energy induces cavitation leading to fat cell lysis while preserving the surrounding vasculature. Cavitation comprises of a complex range of phenomena that involves the creation, oscillation, growth, and collapse of bubbles that results in tissue destruction as a result of mechanical energy.³⁰ A transcutaneous focused ultrasound device that uses noninvasive, nonthermal, focused ultrasound for body contouring has been shown to be effective in preclinical porcine studies in which histologically stained specimens of treated porcine skin and subcutaneous fat tissues demonstrated lysis of adipocytes with no apparent cellular damage observed in adjacent blood vessels, nerves, or connective tissues. Furthermore, there were no histological changes observed in epidermal or dermal tissue samples.³⁰ In early clinical trials, in 164 healthy adult subjects, a single treatment with the Contour I treatment device resulted in approximately a 2 cm mean reduction in treatment area circumference and 2.9 mm reduction in skin fat thickness with no clinically significant changes in the safety parameters measured.³¹ Further evaluation of this technology in a large-scale randomized clinical trial is currently underway.

Benefits of noninvasive body sculpting

Thermal HIFU produces a dual tissue response resulting in the destruction of targeted adipose tissue and collagen contraction. This therapy offers the benefits of a noninvasive procedure in that it reduces treatment time, reduces scarring, and ameliorates the risk of severe posttreatment complications such as infection that are associated with surgical procedures. The HIFU has a well-defined thermomechanical mechanism of action, unlike other noninvasive procedures such as cryolipolysis—the exact mechanism of action for which has yet to be ascertained. Use of the HIFU technology also eliminates the necessity for general anesthesia and the associated risks, thus allowing patients to return quickly to activities of daily living with minimal downtime as compared to a traditional surgical liposuction procedure. HIFU offers an optimum alternative for patients seeking body sculpting who are resistant to the invasive surgery involved in conventional liposuction procedures.

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