A review of techniques and procedures for lipoma treatment

Introduction

Lipomas are benign tumors composed of subcutaneous adipose tissue. They are typically asymptomatic, but may cause discomfort with direct pressure. Removal is typically done for symptomatic or aesthetic purposes. The rare variant of liposarcoma requires aggressive surgical removal and close monitoring for recurrence. Lipomas are typically removed by excision, with potential complications of bleeding, infection, seroma, scarring and recurrence. The following review focuses on the current methods of lipoma excision, as well as alternative removal methods, including cauterization, liposuction, and laser removal. Experimental techniques, such as ultrasound, microwave, and pharmaceutical treatments, are also reviewed.

Background

Physiology of adipose tissue

Subcutaneous fat provides a thermoregulatory and protective function in mammals. It is organized into lobules separated by fibrous septae as shown in Figure 1A. Lobules are collections of fat cells called lipocytes, which are composed primarily of triglycerides. Fibrous septae connect the dermis to the underlying fascia and contain collagen, blood vessels, nerves and lymphatics (1). As individuals gain weight, lipocytes increase in volume. Further weight gain leads to an increase in the number of mesenchymal stem cells which get converted to fat cells. Diet and exercise decrease the size of fat cells; however, the number of fat cells does not decrease, as illustrated in Figure 1B. These new fat cells are referred to as “resistant fat” (2). Abnormal growth may occur within normal functioning adipose tissue, producing lipomatous tumors.

Classification of soft tissue tumors

The World Health Organization Committee for the Classification of Soft Tissue Tumors divides benign lipomatous tumors into nine distinct diagnoses: lipoma, lipomatosis, lipomatosis of the nerve, lipoblastoma/lipoblastomatosis, angiolipoma, myolipoma, soft tissue, chondroid lipoma, spindle-cell lipoma/pleomorphic lipoma, and hibernoma. Each of these characteristic lipomatous tumor types may vary in their...
presentation and treatment. Lipomas composed of mature white adipocytes with uniform nuclei resembling normal white fat are by far the most common lipomatous tumors (3).

**Epidemiology and clinical presentation**

Lipomas are benign tumors of adipose tissue consisting of soft, lobulated masses held together with connective tissue and sometimes encapsulated in a thin, fibrous capsule. Lipomas are the most common soft-tissue tumor, occurring in 1% of the population. Onset occurs most frequently between the ages of 40-60 years. Lipomas can be found in nearly any organ throughout the body, but most are subcutaneous in location (Figure 2) and are, frequently on the neck and trunk. Only occasionally do they involve the fascia or deep muscular plane. They are soft to firm in texture, may be visibly elevated or detectable by palpation, and have no overlying color change. The ‘slippage sign’ may be detected as slight lateral movement when gently maneuvering the edges of the mass. Lipomas are usually asymptomatic and may be observed for changes. Indications for removal include a size larger than 5 cm, pain or discomfort, rapid growth, diagnosis clarification, and cosmesis (4).

The etiology of lipomas remains uncertain. One hypothesis suggests trauma causes fat herniation, leading to the formation of pseudo-lipomas. Another posits that trauma stimulates cytokine release, triggering pre-adipocyte differentiation. No definitive link has been found between trauma and lipoma formation. Some studies have established an association between solitary lipomas and gene rearrangements of chromosome 12 as well as abnormalities in the HMG2-LLP fusion gene (5). Lipomas may be associated with a variety of diseases, including adiposis dolorosa, Madelung disease, Cowden syndrome and Gardner’s syndrome (1).

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Figure 1 - Adipose tissue: (A) in relation to tissue layers and (B) as a result of weight gain followed by weight loss.

Figure 2 - A lipoma located on the right portion of the patient’s forehead, shown from two different angles (photos taken by Dr. William Aughenbaugh).
Lipoma extraction

The following methods and techniques are generally implemented for lipoma extraction.

Pre-operative steps

The borders of the lipoma are marked with a surgical pen, using palpation to detect the edges. The skin is cleansed with chlorhexidine or alternative disinfectant and a ring block is performed using lidocaine with or without epinephrine. The patient is draped to maintain a sterile operating field (4).

Incision and pressure method

The surgeon performs a linear incision about 1/3 to 1/2 the diameter of the lipoma, on the skin directly above the lipoma. Usually Metzenbaum scissors are inserted and spread circumferentially around the tumor in order to break up fibrous bands connecting the fat lobules to the surrounding tissue. Once separated, the lipoma is then expressed applying digital pressure to the edges of the mass. If necessary, a hemostat may be used to provide traction and the incision may be extended to facilitate removal. The resultant cavity is explored to ensure adequate hemostasis and complete removal of fatty tissue. This method of extraction is most effective for encapsulated lipomas but is commonly employed in the removal of non-encapsulated lipomas as well (4).

Punch (enucleation) technique

This method utilizes a 4-6 mm punch biopsy tool, 3 mm curette, tissue scissors, and a hemostat. After pre-operative preparations are completed, the surgeon stretches the skin over the lipoma perpendicular to skin lines. Once taut, the punch tool is centered over the lipoma and is applied with downward pressure and rotation of the tool, removing the epidermis and dermis. A curette is inserted through the incision and the surrounding tissue is scraped with the curette. Once freed, the lipoma is extracted through the incision using a hemostat. Repeated curetting may be necessary in order to deliver portions of the lipoma through the opening. In larger lipomas, multiple small incisions or punches may be necessary for segmental extraction (4).

Elliptical excision method

For large or complicated lipomas, elliptical excision may be necessary. This involves removing a football-shaped wedge of skin in order to maximize visualization of the surgical field. Once exposed, the lipoma is dissected away from the surrounding tissue and removed as a single mass or in segments. While this method results in larger scars than previously described methods, elliptical excision may improve cosmesis by removing excess stretched tissue that arises from slow expansion of the fatty tumor. The removed fat may or may not be sent for histopathologic analysis. Potential complications include bleeding, infection, seroma, scarring, pain and recurrence (4).

Alternative removal methods

There is a desire among patients and clinicians for an alternative method to lipoma excision. The ideal substitute would be a device that is low priced, does not require extensive training and results in minimal scarring. The following sections explore potential removal methods and the extent to which they have been tested.

Cauterization

Cauterization involves using heat to burn away segments of tissue. Although cauterization has not been widely tested in removing subcutaneous lipomas, it has been used extensively in other areas of surgery. Several unique instruments have been developed to deliver heat to tissue.

Electrosurgery

In electrosurgery, heat is created by passing a high-frequency alternating current through the desired tissue. This method comes in a monopolar form, in which the current passes through the body, and a bipolar form, in which the current flows between the tines of a forceps. Complications of electrosurgery include scarring, burns, interference with pacemakers, and production of surgical smoke (6).

Harmonic scalpel

The harmonic scalpel is another technique for using heat to remove tissue. In this method, a mechanical vibration of 55.5 kHz is induced in the scalpel. This rapid movement results in high amounts of friction with the tissue, resulting in heat. The harmonic scalpel is subsequently able to cut and coagulate simultaneously. Compared to electrocoagulation, the harmonic scalpel has been shown to reduce operative time (7). This method is not commonly employed for cutaneous surgeries because it does not result in a clean cut at the surface.

Liposuction

Typically performed as a cosmetic procedure, liposuction may be used to remove fat. With this technique, subcutaneous fat is removed via a low suction cannula.
M. Boyer et al.

Liposuction allows surgeons to make incisions at specific locations to maximize cosmetic outcomes. During a typical liposuction operation, several small about 1 cm, incisions are made at strategic locations surrounding the target area (2). In wet liposuction, fluid is infused in order to loosen adipose tissue and reduce bleeding. Anesthetics may be included to reduce pain. Dry liposuction describes the removal of fat without injecting fluid to the surgical field (8). A smaller cannula 1 mm, is first used to create tunnels in the fat (2). Cannulae of gradually increasing diameter are then employed to aspirate fat. The most important aspect of proper aspiration is the slow, repeated, to-and-fro movement of the cannulae. Deeper layers of fat are aspirated first and then the superficial layers. Multiple different liposuction techniques exist in order to properly remove adipose tissue.

**Conventional liposuction technique**

The conventional liposuction technique begins by creating relatively large incisions 1-1.5 cm near the target area. A larger cannula 0.6-1 cm in diameter is then introduced into the subcutaneous layer to aspirate the adipose tissue. This process may be performed under “dry” or “wet” conditions, and the patient is typically under general anesthesia. The larger cannulae and larger incisions makes this technique very fast and effective, however, this method requires hospitalization due to the general anesthesia and typically results in more significant scarring (2).

**Tumescent liposuction technique**

In tumescent liposuction, 4-8 small incisions of 1-3 mm at key locations are performed in the target area. Large quantities about 1-4 L of Klein’s fluid, composed of saline, dilute epinephrine and lignocaine, are injected. The saline balloons fat tissue, epinephrine causes vasoconstriction, and lignocaine induces local anesthesia. A microcannula, typically 1.5-3 mm in diameter, is introduced to aspirate adipose tissue (2, 9). Since the tumescent technique is one of the only liposuction methods that only requires local anesthesia, the procedure does not require hospital admission and is associated with a rapid postoperative recovery time. However, this technique is particularly expensive to perform, and the removal of adipose tissue is considerably slower than in the conventional technique.

**Power-Assisted Liposuction (PAL)**

Power-assisted liposuction is similar to the conventional technique, but it includes a reciprocating cannula, which mimics the to-and-fro piercing motion typically made by the surgeon. This technique is especially useful in areas with lower surgical mobility such as umbilical and waist areas, as it allows surgeons to remove fat more completely without expanding the existing incisions. While it increases the ease of the procedure for the surgeon, PAL has the same shortcomings of conventional liposuction, including general anesthesia and a large cannula (2).

**Ultrasound-assisted liposuction**

The incorporation of ultrasound allows the surgeon to damage fat cells, facilitating their removal. This is accomplished through the use of an ultrasound emitting probe on the cannula, breaking down tissue as it is aspirated. However, the use of this technique has been found to cause a number of serious side-effects, such as burns to the skin, seromas, and prolonged post-operative swelling. The use of ultrasound significantly increases the cost of the procedure due to the additional equipment required (2). In the case of lipoma extraction, liposuction is used to mechanically break up fat lobules and fibrous septae. The lipoma is then extracted through an incision typically 1 cm using a forceps (8).

The use of liposuction in the treatment of lipoma is limited primarily by cost. One reason for the high costs of liposuction is due to the extensive training required. Physicians in the United States performing liposuction must graduate from an accredited medical school, complete at least five years of residency training, and obtain certification from a surgical board recognized by the American Board of Medical Specialties (9, 10). If the surgeon does not have sufficient experience in residency, they may also complete a liposuction/body contouring training course approved by the board. Comprehensive hands-on courses on liposuction training alone may cost $4000–$8000 per surgeon for two days of training, and the cost of completing the certification exams and paying the maintenance fees required for certification alone might cost upwards of $3000 according to the American Board of Internal Medicine (11).

The cost of liposuction varies by the location and size of the tumor. Due to the high costs of proper certification and operations, the use of liposuction in the removal of lipoma is typically avoided (12).

**Lasers**

Lasers are an alternative method to removing excess adipose tissue. While commonly used in cosmetic applications, laser assisted removal of lipoma is more of an experimental technique. Carbon dioxide (CO₂) lasers can be used for tissue ablation (13). CO₂ lasers use an infrared beam to excite the water molecules in the target tissue and heat the cells. This heat can damage and destroy the target tissue. The adipose tissue can be either melted or vaporized, depending on the power supplied. The intensity of the laser can be varied between 3-8 W, providing added control and limiting side effects (14). The applied energy of the laser is focused, resulting in a high precision and
A review of techniques and procedures for lipoma treatment

accuracy, thereby reducing damage to healthy surrounding tissue. These methods are often used in delicate procedures, such as lipoma in the spinal cord (15, 16). Additionally, lasers can be used when complete removal of the mass is necessary, as in the case of malignant lipomas.

While laser technology has been available for several decades, it is rarely employed for lipoma removal (17) due to lack of maneuverability in small areas. Because of the rather large and cumbersome design, they are not ideal in the setting of small skin incisions. Additionally, heat transfer from the laser and cauterized tissue can cause unwanted damage to surrounding tissue. Lasers also cannot stand alone as a technique for lipoma extraction. Because cauterized edges tend to not heal together, lasers must be used in conjunction with traditional methods.

However, in response to the lack of flexibility, a flexible hollow core CO2 laser has been created by Omniguide (18). The Omniguide laser system uses fiber optics to transmit CO2 laser energy through a flexible tube. In their 2012 study, this system was tested on eight patients that had subcutaneous lipomas in the lumbar region. The laser was powered between 4-8 W and used to vaporize the lipomatous tissue. The cutting of the tissue was done at a range of 2-4 mm from the tip of the laser. The procedure resulted in successful resection of the lipoma without any nerve damage in all eight patients.

Experimental methods

**Non-invasive ultrasound**

Ultrasound is often associated with medical imaging and detection. It functions by emitting high frequency sound waves and detecting the return signal. A High-Intensity Focused Ultrasound (HIFU) is an application of ultrasound involving a transducer to focus the energy waves at a discrete point. This allows for heat energy to be delivered to a chosen point at a distance from the source without injuring the intervening tissue. This heat energy raises the temperature at the focal point to above 80 °C, resulting in coagulative necrosis and tissue destruction.

Shemer et al. (19) tested HIFU to non invasively reduce lipoma size. The study involved twelve lipomas and nine patients, which underwent four separate HIFU treatments over the course of three weeks. Blood and urine were tested to determine side effects. The results of the experiment showed a mean reduction of lipoma volume of 58.1 ± 22.8%, with no significant adverse effects (19).

The UltraShape Contour I System is a HIFU system, which has been FDA approved for “abdominal circumference reduction by mechanical disruption of fat cells”. A study was conducted to determine the efficacy of this product to improve the appearance of body contours in twenty-five women. The test consisted of three 30 to 90 min treatments at two-week intervals. There were no adverse events reported, but only twenty-three of the twenty-five subjects reported no pain. A significant reduction of midline circumference, 3.12 cm on day 112 was reported. Although the Contour I System has not been used nor approved for lipoma removal, the study indicates that HIFU systems could potentially be used for adipose tissue disruption. The area of a lipoma is much smaller than the area covered in this study, suggesting that its use as a lipoma-removal method may be even safer due to a likely reduced operation time (20). Cost and further research remains a limiting factor with this technology.

**Non-surgical chemical injections**

Although there have been numerous studies of different pharmaceutical approaches to lipoma removal, no injectable drugs have been approved by the FDA for lipoma treatment. The injection of Phosphatidyl Choline (PDC) coupled with Deoxycholate (DC) is a commonly studied pharmaceutical approach that has proven to be successful in reducing the size of lipomas. Additionally, steroid, statin and collagenase based formulations have been proposed as other non-surgical treatments for lipoma reduction (21).

**Phosphatidyl choline/deoxycholate**

Phosphatidyl Choline (PDC) is a cell membrane component that has been traditionally coupled with Deoxycholate (DC) for the cosmetic reduction of the amount of local fat tissue (22, 23). PDC was originally combined with DC in order to solubilize the formula; however, some studies have suggested that DC alone is the major contributor to lipolysis (24). Rotunda et al. (25) revealed that PDC/DC treatment resulted in a slightly higher reduction in lipoma size than did DC alone, which suggests that both components contribute to the degradation of fatty tissue. When applied to lipomatous tissue, PDC/DC has yielded a decrease in lipoma size in multiple studies (26, 27).

Side effects of PDC/DC treatment include bruising, erythema, edema, and pruritus. The cell lysis function of DC is not selective towards adipose tissue, and lysis of muscle cells has been observed. Therefore, PDC/DC must be administered accurately to specifically target fat cells. PDC/DC may also alter the fibrous capsule, making the lipoma harder to remove via excision if it is to regrow (23).

**Steroids**

Both triamcinolone acetonide and a corticosteroid with a β2 agonist have been used to reduce the size of lipomas in humans. Salam (28) proposes the injection of a one-to-one mixture of 1% lidocaine and triamcinolone acetonide (10 mg/mL) given at monthly intervals. The β2 agonist isoproterenol was used in conjunction with prednisolone in an attempt to stimulate lipolysis in...
a lipoma (29). The β-adrenergic stimulation of adipose tissue causes local lipolysis while reducing the overall systemic toxicity of treatment. However, β-adrenergic stimulation also down-regulates β2-receptors, slightly diminishing the efficacy of the injected agonist. The β2-adrenergic receptor stimulation is important to lipolysis because it reduces the release of glycerol, which is also observed in response to extended periods of aerobic exercise. The corticosteroid functions to increase the number of β2-adrenergic receptors in the fatty tissue and eliminates their down-regulation. The results of this study revealed an increased magnitude of lipolysis when isoproterenol was used with prednisolone, as opposed to isoproterenol alone. The most effective concentration of isoproterenol was 10-6 M, which caused a 50% reduction of the size of the lipoma. Only one lipoma did not regrow after the treatment and the majority of the subjects chose to have their lipomas removed surgically (29).

Collagenases

Phase 2 clinical trials on a collagenase based injection, by BioSpecifics Technologies Corporation is designed to eliminate the fatty tissue of a lipoma. The drug used in this method is Collagenase Clostridium Histolyticum (CCH). In the trial, four different dosages were given to 14 patients with lipomas, and caliper measurements on the surface area of the lipoma were used to assess the efficacy of the treatment. The caliper measurements were taken six months after the treatment. The best results were seen in the group with the highest dose level, 75% of commercial dose, in which an average of 67% reduction of the lipoma was observed. Side effects of the CCH injection included bruising, swelling, and pain at the injection site (30).

Microwave ablation

Similar to ultrasound, microwaves have been used to selectively heat and ablate tissues. An antenna is used for microwave radiation at a selected location. The antennae are insulated, except at the portion that is used to propagate the energy wave. Additionally, each antenna is specifically designed for a singular frequency and distribution pattern (31). Although there is limited literature regarding microwave antenna usage for lipomas, many studies have proposed the use of microwave radiation to soften adipose tissue prior to or during liposuction procedures. To minimize the risk of causing damage to tissue surrounding the target site, ISO standard 60601-2-33 requires that the temperature at any single point should not exceed 50°C for a period of 10-60 min. In a study by Rosen et al. (32), swine adipose tissue was treated in vivo with a novel microwave antenna/cannula probe that was powered in the range of 30-40 W, resulting in the suction of a creamier, less bloody, and more liquefied fat than was observed in non-microwave-assisted liposuction. Additionally, well-treated areas of the adipose tissue revealed a destruction of septa between fat lobules (32).

Combination technologies

Of the experimental and currently applied approaches listed in the previous sections, many are combined in order to produce new lipoma extraction techniques. These techniques are largely described in patients, which combine two or more technologies in order to combat lipomatous tumors, with varying degrees of design progression over time.

Liposuction procedure with ultrasonic probe

Massengill and Parisi (33) proposed a customized liposuction probe, which is ultrasonically vibrated at high frequencies and low amplitudes creating localized tissue separation and frictional heat. The probe closely resembles a cannula, adapted to provide a localized flow of irrigating fluid, serving to emulsify the melted and separated fat.

Method and apparatus for microwave aided liposuction

Rosen and Rosen (34) proposed design consisting of a microwave generator coupled to the distal end of an electromagnetic transmission line. This transmission line emits radiation from the antenna into the fatty tissue adjacent to the distal suction port of the suction lumen, heating and softening tissue. In another embodiment of the invention, the transmission line is formed so that the electromagnetic field extends into the suction lumen. This extended radiation field causes the fatty tissue being removed to remain heated and softened while being transported through the cannula. In addition, saline solution or a similar liquid with polar molecules is injected into the region being treated to provide improved coupling of energy between the electromagnetic radiation and the fatty tissue. This solution may then be removed via the suction lumen, just like the removed adipose tissue. Microwave radiation may also be applied to the region being treated by means of an external radiator. The heating effect of the radiation not only softens the tissue for ready removal, but may also sterilize the region for reducing infection (34).

Laser-assisted liposuction method and apparatus

The laser-assisted liposuction method and apparatus utilizes a liposuction cannula consisting of a water source, a laser source, and a suction source. This technique releases water into an active area within the cannula, and directs laser energy onto the water molecules. This energizes the water molecules, inducing
molecular friction and a resulting rise in the water temperature. The energized water molecules escape from the active area of the cannula into the surrounding fatty tissue. The water breaks down the fatty tissue into a liquid material, which is removed by aspiration via the cannula (35).

Freezing method for controlled removal of fatty tissue by liposuction

The freezing method for the controlled removal of fatty tissue combines cryosurgery and liposuction. The application of cryosurgery in addition to liposuction destroys fatty tissue by controllably freezing the tissue and facilitating adipose removal. Following the tissue destruction, traditional liposuction techniques may be applied to subsequently remove the destroyed fatty tissue by aspiration (36).

Conclusion

Although lipoma affects a large portion of the population, the majority of removal procedures for subcutaneous lipomas are still performed with a standard set of scalpels and scissors. Unfortunately, the standard methods can result in significant scarring. The most effective adipose tissue removal method that is FDA approved is liposuction, but the required equipment and training are cost prohibitive for many surgeons. New methods are desired to effectively remove an entire lipoma with reduced scarring and costs. Ultrasound and pharmaceutical methods have shown promise, but still require FDA approval. Laser technologies have been effective for deeper lipomas, but require very large incisions. Our society and the industry would benefit from the development of a novel, directed approach to lipoma excision, which may utilize a combination of components from the many emerging technologies.

Acknowledgements

There are no potential conflicts of interest and/or sources of funding for all authors involved in the writing of this manuscript.

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