Tumescent Technique Chronicles

Local Anesthesia, Liposuction, and Beyond

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This article is a personal view of the history of the tumescent technique and a look at its future. Invented and popularized by dermatologists, the tumescent technique has consequences far beyond dermatologic surgery.

As a local anesthetic technique the tumescent technique has revolutionized liposuction by eliminating both the risks of general anesthesia and the massive bleeding once associated with liposuction. Its vasoconstriction has permitted the extensive use of microcannulas and superficial liposuction, thus dramatically improving anesthetic results.

The reality of tumescent liposuction is just the opposite of what one might expect based on common sense and experience. The dilution of a local anesthetic solution of lidocaine and epinephrine does not weaken its effect, it actually enhances the degree of anesthesia, and vasoconstriction. Although microcannulas remove less fat per unit of time, they actually permit the removal of greater volumes of fat than traditional liposuction cannulas with diameters of 6-10 mm. Patients find that there is less pain associated with tumescent liposuction than liposuction by general anesthesia. It is disconcerting when clinical expectations are not congruent with clinical reality. However, the concept is better understood, its applications will extend well beyond its present horizon.

Definitions

A microcannula is defined as liposuction cannula with an inside diameter (ID) of less than 2.0 mm. The small cross-sectional area of a microcannula requires minimal force to penetrate the tough fibrous septa within adipose tissue and allows greater directional control. Greater accuracy and minimal risks of residual skin irregularities allow more superficial liposuction, more complete extraction of fat, and ultimately greater patient satisfaction. In addition to microcannulas, slightly larger cannulas having IDs of 2.2 and 2.7 mm are routinely used with tumescent liposuction. (Table 1)

Table 1. Sizes of Micro-Cannulas

Cannula Gauge	Lengths (cm)
16 (1.2 mm)	5, 7.5
14 (1.6 mm)	10, 15, 22.5
12 (2.19 mm)	10, 15, 22.5
10 (2.7 mm)	10, 15, 22.5

The tumescent technique is a method of drug delivery using a relatively large volume of an exceptionally dilute solution of drug(s), usually in combination with a dilute vasoconstrictor such as epinephrine, infiltrated directly into localized compartment(s).

As a novel means of drug delivery, the tumescent technique has potential applications far beyond the domain of dermatologic surgery. From a theoretical point of view there are several pharmacologic actions that the tumescent technique can provide (Table 2).

Table 2. Goals of the Tumescent Technique

Optimize biochemical and/or biomechanical drug efficacy
Target drug effects in local tissue compartments
Maximize drug concentration locally
Delay systemic drug absorption
Prolong local or systemic drug effects
Decrease systemic drug toxicity, and increase the safe upper limit of drug dosage
Mechanically expand a targeted compartment
Benefit from augmented local hydrostatic pressure

Tumescent liposuction is defined as a combination of the tumescent technique for local anesthesia and a specific method for liposuction . Tumescent liposuction achieves regional local anesthesia of the skin and subcutaneous tissue by direct infiltration of dilute lidocaine, epinephrine, and sodium bicarbonate into the targeted subcutaneous fat. Tumescent liposuction also involves specific surgical methods including the use of microcannulas inserted through multiple small incisions. In order to encourage copious postoperative drainage, these incisions are not closed with sutures.

The current formulation of the local anesthetic solution for tumescent liposuction is described in Table 3. Formulations for tumescent local anesthetic solutions used for other surgical procedures are described elsewhere.[1] In addition to liposuction the tumescent technique has many actual and potential applications (Table 4).

Table 3. Formulation of the Local Anesthetic Solution for the Tumescent Liposuction Technique

Ingredient	Quantity	Approximate Concentration
Lidocaine	500-1,000 mg	0.05-0.1%
Epinephrine	0.50-0.65 mg	1:2,000,000-1,1,500,00
Sodium bicarbonate	10 meq	
Triamcinolone	10 mg	
Physiologic saline	1, 000 ml	

Other formulations are used for procedures other than liposuction.

Table 4. Applications of the Tumescent Technique

Actual
  Local anesthesia and hemostasis for:
    Liposuction
    Facelift
    Dermabrasion
    Hair transplantation
    Large cutaneous surgeries
      Abdominoplasty
      Flaps
      Skin Grafts
      Excision
    Hemostasis for mastectomies
    Topological transformation of tissues: mechanical elevation of skin from subjacent
    neurovascular structures.

  Potential
    Targeted delivery of drugs to peripheral lymphatics
      Cancer chemotherapy and immunotherapy
      Immunotherapy: vaccine delivery for T-cell mediated immunity
    Delivery of radiopaque contrast media targeting lymphatics
    Snake antivenin therapy
    Resuscitation: fluid and electrolyte replacement in trauma, burns, cholera.
    Focal hemostasis and infection prophylaxis in surgical field

Local Fallacies

In the early 1980s the pharmacology and absorption kinetics of local anesthesia in skin and subcutaneous tissue were considered trivial, uninteresting, and unworthy of systemic investigation. Years of well-published pharmacokinetics orthodoxy had convinced most surgeons and anesthesiologists that it was impossible to do moderate volume liposuction by local anesthesia. Several fallacious assumptions, many of which persist today, have obscured the potential efficacy of local anesthesia.

Fallacy I: The duration of lidocaine is only effective as a local anesthetic for a relatively short time; and the higher the concentration, the longer the duration of anesthesia.[2]

Fallacy II: Peak plasma lidocaine levels occur within 60-90 minutes after subcutaneous infiltration. [3,4]

Fallacy III: Most of the lidocaine infiltrated for tumescent liposuction is removed along with the aspirated fat.[5,6]

Fallacy IV: Minimally effective concentration of lidocaine for local anesthesia of skin is 0.4% (0.4 g/100 ml).

Fallacy V. Bupivicaine is as safe as lidocaine, and the combination of lidocaine and bupivicaine for liposuction by local anesthesia is safe and rational.

Fallacy VI: Lidocaine dosage restrictions (7 mg/kg with epinephrine) should be the same for all forms of local anesthesia including epidural, axillary, or intercostal nerve block, and subcutaneous and intradermal infiltration.[7,8]

Fallacy VII: The rate of absorption is independent of the concentration of the infiltrated lidocaine.[9]

Having initially accepted the validity of these assumptions, a little clinical experience convinced me that they were wrong. There are many who still accept the validity of these misconceptions.

Antediluvian Liposuction

For many years general anesthesia was an absolute requirement for liposuction. The standard cannulas of the 1980s were huge, having diameters of 6-10 mm and cross-sectional areas 9-25 times greater than today's 2-mm microcannulas.

The first written description of liposuction was published by Fischer of Italy in 1977. Soon afterwards the French surgeons Illouz and Fournier popularized liposuction using blunt-tipped cannulas. The common adverse sequelae of liposuction were excessive bleeding, prolonged recovery time, and disfiguring irregularities of the skin. Preoperative infiltration of a small volume of a vasoconstrictive solution of epinephrine into the targeted fat was termed the wet technique. Using no preoperative infiltration was known as the dry technique. These coeval antiquated techniques are still used today and continue to produce massive bleeding and often require transfusion.

By 1982, several American dermatologists had been to France to observe Illouz do liposuction using general anesthesia together with a subcutaneous injection of a small volume of a hypotonic solution of epinephrine and hyaluronidase.

By 1983, dermatologists were doing liposuction of lipomas, the submental chin, and limited areas of the body using general anesthesia, epidural regional anesthesia, or heavy IV sedation supplemented by small volumes of local anesthesia. The IV sedation usually involved diazepam and a narcotic analgesic, while the local anesthesia usually consisted of 0.25-0.5% lidocaine with epinephrine 1:200,000. Dermatologists who were prominent in teaching the technique included Drs. Sol Asken, Larry Field, and Richard Glogau.

In late 1984, having just completed residency training and board certification in dermatology, starting a private practice and learning more dermatologic surgery were my primary concerns. At that point, my years of study, that had included masters degrees in mathematics and public health biostatistics, National Institutes of Health research fellowships in clinical pharmacology, and board certification in internal medicine seemed of little practical utility. In retrospect, these years of training provided the concinnity of experience and knowledge that produced the concept of the tumescent technique.

Ironically, upon first hearing about liposuction, my impression was a mixture of curiosity, amusement, and disdain. It was Larry Field, a pioneer of modern dermatologic surgery, who

convinced me that liposuction was destined to become an important dermatologic surgical procedure. In February 1985, I attended a liposuction course given by Gary Fenno, MD and sponsored by the American Society for Liposuction Surgery. None of the faculty had done liposuction by local anesthesia. Liposuction by local anesthesia was thought to be impractical if not impossible. The plastic surgery literature stated, without discussion, that liposuction required general anesthesia.

In early 1985, using local anesthesia, I performed my first liposuction procedure. By the end of that year, an elementary form of the tumescent liposuction with IM diazepam (Valium[TM] sedation and meperidine (Demerol [TM]) analgesia had evolved. The tumescent technique was first described in a talk I gave at the Second World Congress of Liposuction Surgery sponsored by the American Academy of Cosmetic Surgery held in Philadelphia in June 1986. The first article describing the tumescent technique was published in the American Journal of Cosmetic Surgery in January 1987.[10]

At this point in time, some surgeons, who insisted upon doing liposuction by general anesthesia using a technique that often required blood transfusions, were stating publicly that only they were sufficiently trained to do liposuction safely. Meanwhile a number of dermatologists, including Drs. William Coleman, Patrick Lillis, and Rhoda Narins, were busy teaching their dermatologic colleagues how to do tumescent liposuction totally by general anesthesia with virtually no blood loss.

Subsequent years have seen continual improvement. With the tumescent technique, liposuction is now a procedure of exceptional finesse and gentleness that is accomplished totally by local anesthesia. And this process of evolution and refinement is continuing.

Dermatologic Origins of Tumescent

A preference of local anesthesia, an aversion to the high costs of hospital operating rooms, and an impertinent skepticism of established surgical dogma explain why it is dermatologists who invented the tumescent technique.

The tumescent technique has a natural appeal to dermatologists and is uniquely compatible with traditional dermatologic surgical training. Dermatologists prefer local anesthesia for skin surgery and prefer to avoid the complications associated with general anesthesia. They are more likely to have the training, the patience, and the personality to deal with patients who are awake and alert. Without such qualifications, it is nearly impossible to do liposuction without general anesthesia, IV sedation, or narcotic analgesia.

The perceived value of the tumescent technique depends on the surgeon's education. Training that inculcates a preference for general anesthesia usually does not emphasize the benefit of having an awake patient. The distinction between necessary and convenient forms of anesthesia is often disregarded. Extensive training with general anesthesia does not afford much opportunity to acquire the experience and temperament needed to manage an alert patient during surgery. On the other hand, most dermatologic surgeons are exclusively trained to use local anesthesia. Using general anesthesia is rarely necessary nor desirable.

In light of these distinctions, it is not surprising that dermatologists invented and popularized the tumescent technique for liposuction totally by local anesthesia.

The 7 mg/kg Prevarication

The standard dosage of lidocaine with epinephrine for infiltration anesthesia is authoritatively stated to be 7 mg/kg.[11] There were several clues that the 7-mg/kg dose limit for lidocaine might be wrong.

First, there is no scientific publication to support 7 mg/kg as the maximum safe dose of lidocaine with epinephrine when infiltrated into subcutaneous tissue. To a certifiable skeptic, this little bit of pharmacologic obfuscation was a conspicuous hint of the existence of an untrustworthy "fact."

Second, an experimental study of the lethal dosage of lidocaine published in 1948 reported that the LD_{50} of subcutaneous lidocaine in mice was inversely proportional to drug concentration. This supported the conjecture that extremely dilute solutions of lidocaine might permit safe doses significantly greater than 7 mg/kg.

Third, many surgeons, including myself, wrongly assumed that liposuction removed a significant amount of lidocaine along with fat. This assumption would seemingly permit a greater safe dose of lidocaine. This motivated the habit of infiltrating just one area and then doing liposuction before infiltrating the next area.

Finally, when blood was sampled 1 hour after a lidocaine dose of 10-20 mg/kg by the tumescent technique, the plasma concentrations were less than 0.3 ųg/ml, well below the 5- ųg/ml threshold for early lidocaine toxicity. This finding provided a confidence, albeit naive, that lidocaine toxicity was a remote risk. This erroneous assumption was based on the belief that peak plasma lidocaine levels occur within 2 hours after infiltration. The perfunctory explanation was that lidocaine was being rapidly metabolized in the liver. Only later was it realized that the peak lidocaine plasma levels were higher and occurred up to 12 hours after completion of tumescent liposuction.

Defying Dogma

In 1987, many surgeons believed that liposuction was safer by general anesthesia than by local anesthesia. A dose of lidocaine in excess of 7 mg/kg was considered more dangerous than either using general anesthesia or the excess surgical bleeding that routinely required autologous blood transfusion.

The Food and Drug Administration (FDA), the sanctifier of scripture relating to promotional information for any drug sold in the United States, must approve every word of a manufacturer's informational package insert. In 1948, when Astra Pharmaceuticals obtained approval to market lidocaine (Xylocaine[TM]), FSA requirements for substantiation of dose limits were not demanding. In fact, the only justification for the "official" maximal safe lidocaine dosage, 7

mg/kg, was a letter from Astra to the FDA that simply stated, "the maximum safe dosage of lidocaine is probably the same as for procainamide."

As a published summary of FDA-approved drug information, the *Physicians' Desk Reference* (PDR) has an aura of infallibility comparable to divine scripture. It was dangerous heresy to advocate a lidocaine dosage greater than 7 mg/kg. At a medical meeting in 1987, my report of using 15 mg/kg of lidocaine for tumescent liposuction provoked a public accusation of medical malpractice.

Even today, despite the results of several well documented studies validating the estimate of 35 mg/kg as a safe upper limit for a lidocaine dose with the tumescent technique for liposuction, many surgeons and anesthesiologists persist in a fundamentalist interpretation of the PDR. To the potential detriment of liposuction patients, they continue using antiquated techniques associated with massive bleeding, and potentially fatal complications connected with general anesthesia.

The First Case

The first liposuction that I performed was on April 5, 1985. The volunteer patient, Annie McCoy, RN, had a localized accumulation of fat on the lower abdomen above a transverse hysterectomy scar.

Using only 50 ml of a commercially available local anesthetic formulation containing 500 mg of lidocaine (1%) and 0.5 mg of epinephrine (1:100,000), the result of the procedure was encouraging, but less than satisfactory. Approximately 45 ml of fat was removed. The degree of hemostasis was profound with the aspirated fat containing almost no blood. However, the volume of fat that could be anesthetized using only 50 ml of local anesthetic was too small. The 05. mg of epinephrine at a concentration of 1:100,000 caused tachycardia. The most painful part of the procedure was the burning-stinging sensation caused by the infiltration of the local anesthetic. The actual liposuction, while not painless, was more easily tolerated than the infiltration.

Annie returned for a more extensive liposuction of the lower abdomen and lateral thighs 1 month later. On this occasion, the anesthetic solution was more dilute, and the results were better with fewer side effects. The anesthetic solution consisted of lidocaine (2,000 mg/L) with epinephrine (2 mg/L) in 1,000 ml of physiologic saline, yielding a formulation of roughly 0.2% lidocaine and epinephrine 1:250,000.

This concentration of epinephrine still produced tachycardia (approximately 120/min) but the hemostasis was superb. The aspirate contained 450 ml of bloodless fat and 100 ml of mildly blood-tinged infranatant anesthetic solution. Pain upon infiltration was eased with IM meperidine and diazepam. Lidocaine at a 0.2% concentration was clearly effective and well below the 0.4% (4 gm/L) concentration that was, at that time, the published minimal effective concentration for cutaneous local anesthesia.

Clearly there was a need to perfect the formulation of the anesthetic solution. What might be the minimum concentration of lidocaine and epinephrine? What might be the maximum safe total dose of lidocaine?

Lidocaine: Minimum Effective Concentration

A review of the literature on lidocaine found no studies specifically concerned with local anesthesia of subcutaneous fat. It was clear that the minimally effective concentrations of lidocaine and epinephrine for cutaneous and subcutaneous local anesthesia were not well defined.

Any estimate of the minimal effective lidocaine concentration depends upon multiple variables associated with the surgical technique and patient traits. Surgical factors include the completeness and the uniformity of anesthetic infiltration, the surgeon's finesse and skill, the cannula diameter, and personality traits of the surgeon and nursing staff. Patient-dependent variables included the anatomic location of the fat, the patient's age and sex, and patient's anxiety level. Any use of anodyne drugs such as narcotic analgesics or IV sedatives also affects the threshold of pain. With more clinical experience, it became apparent that a formulation consisting of 0.1% lidocaine (1 gm/L) and 1:100,000 epinephrine (1 mg/L) was effective. However, because of the burning-stinging pain upon infiltration persisted, the process of infiltration was not easily tolerated.

The range of lidocaine concentrations currently recommended for tumescent liposuction totally by local anesthesia is 500-1,000 mg/L. This range was derived with the cooperation of several patients by comparing the subjective effect of a given lidocaine concentration on one thigh and a slightly lower concentration on the opposite thigh. More patients can distinguish between 0.04% and 0.05% lidocaine, than between 0.5% and 0.6%.

Years of clinical experience have shown that 0.075% lidocaine (750 mg/L) is sufficient for liposuction, totally by local anesthesia, of the extremities, hips, and neck/facial areas, provided one uses microcannulas and careful infiltration.

Lidocaine at 0.1% (1,000 mg/L) provides more consistent anesthesia for the more fibrous or the more sensitive areas such as the periumbilical area and the abdomen, female infrascapular and posterior axillary areas, male flanks, and male breasts.

Epinephrine: Minimum Effective Concentration

The vasoconstriction associated with epinephrine has three consequences for tumescent liposuction: it prolongs the local anesthetic effect, it slows the rate of absorption of lidocaine permitting greater doses of lidocaine, and it produces such dramatic hemostasis that clinically significant surgical blood loss is eliminated.

The minimally effective epinephrine concentration was derived by careful clinical observation of cutaneous blanching and pulse rate. Experience has shown that epinephrine (0.65 mg/L)

provides consistently excellent vasoconstriction for many hours, with a very low incidence of tachycardia.

Lidocaine: Maximum Safe Dose

The search for a better estimate of the maximum safe dose of lidocaine involved some trepidation. The illuminati of aesthetic surgery felt compelled to publicly state that dermatologists were incapable of doing liposuction safely.

Self-preservation demanded prudence and good documentation in following an intuitive hunch that 7 mg/kg grossly underestimated the maximum safe dose for tumescent lidocaine. After having established that 0.1% lidocaine is effective, this concentration was maintained constant, while a total volume of solution, and thus the total dose of lidocaine, was cautiously increased. Careful clinical observation revealed absolutely no evidence of early lidocaine toxicity as doses were incrementally augmented during succeeding surgeries.

On April 10, 1988, after liposuction on a nurse's husband, I casually asked her to obtain a few extra venous blood samples at home for determination of additional lidocaine blood levels. Sequential blood samples over 7 hours produced unexpected results. The blood levels increased linearly with time, indicating that the maximum concentration occurred well after 7 hours. Forthwith, with another patient, lidocaine blood levels were determined over a 24-hour interval and showed a maximum at 12 hours. This finding was unprecedented. The prevailing belief was that peak lidocaine blood levels occur less than 2 hours after infiltration. By repeating this study with additional patients, it was determined that peak lidocaine blood levels for tumescent liposuction occur 12 ± 3 hours.

By graphing the magnitude of the peak concentrations as a function of dose (mg/kg), a safe dosage for tumescent lidocaine was shown to be at least 35 mg/kg.[12] This provided scientific justification for lidocaine doses five times greater than the 7-mg/kg limits stated in the PDR. Previously, in its first published description, it was shown that the tumescent technique eliminates significant liposuction blood loss.[13] These two findings were revolutionary, and established dermatologic surgery as the authority on safe liposuction surgery.

Improved Anesthetic Formulation

Adding sodium bicarbonate (10 meq/L) to the anesthetic solution eliminated the burning-stinging pain associated with the acidic pH of commercially available lidocaine preparations.[14-16] This simple modification provided a quantum jump in patient comfort and safety. It eliminated the need for parental sedation with benzodiazepines and narcotic analgesia. It eliminated the need for pulse oximetry and its attendant hassles. It was the key to large volume liposuction *totally* by local anesthesia.

It has been my clinical impression that adding triamcinolone (10 mg/L) to the anesthetic solution decreases postoperative inflammation and soreness. Triamcinolone, with its low solubility in water and high partition into lipids, tends to persist locally where infiltrated. Its anti-

inflammatory effect reduces symptomatic soreness for up to 6 days postoperatively. It is now a standard part of the anesthetic solution for tumescent liposuction.

The use of a peristaltic infiltrating pump has made it possible to use a tiny 25-gauge spinal needle for the initial stages of infiltration. This has further reduced the discomfort associated with infiltration into the most fibrous areas of fat such as the knees, upper abdomen, the back and flanks, and male breasts. Furthermore, the pump has eliminated the need for the "brute strength" needed to infiltrate using a syringe, and has thereby permitted nurses to do the infiltration.

Hemostasis Permits Microcannulas

One of the least expected consequences of the tumescent technique is that its profound hemostasis permits the extensive use of microcannulas.

Prior to the tumescent technique, blood loss was a limiting factor in determining how much liposuction could safely be done. As shown below, microcannulas cause more surgical bleeding than larger diameter cannulas. Thus, without good hemostasis liposuction surgeons naturally preferred to use large cannulas. By eliminating significant blood loss, the advantages of microcannulas can be realized.

The shape of the wound within fat made by a liposuction cannula is approximately a cylindrical tunnel with a circular cross-section. It can be shown that the relation of the surface area (A) of a cylindrical tunnel to its radius (R) is given by the equation $A = 2 V/R$, where V is the volume of a cylinder. In other words, for a fixed volume, the surface area of a cylinder is inversely proportional to its radius (Figure 1). – not included in this doc

Now, suppose that a particular patient has equal volumes of fat removed by liposuction from each outer thigh, using a small diameter cannula on one thigh, and a larger cannula on the opposite thigh. For this fixed volume of fat, the smallest diameter cannula will have the largest surface area associated with its cylindrical wound. It should be clear that the larger the surface area of a cylindrical wound within fat, the greater the number of transected capillaries, and thus the greater the amount of bleeding. Thus, earlier and bloodier liposuction techniques had to use larger cannulas in order to minimize bleeding.

Microcannula Specifications

Tumescent liposuction microcannulas (ID ≤ 2.0 mm) are constructed from fully hard-tempered, 304 stainless steel hypodermic needle stock. Cannula size is denoted by the corresponding needle gauge. The 16-gauge cannula, used for liposuction of the face and neck, and for relatively thin patients, has an inside diameter (ID) of 1.2 mm. The 14-gauge (1.6 mm ID) is the cannula I use most frequently. The 12-gauge (2.2 mm ID) and the 10-gauge (2.7 mm ID) are larger than microcannulas and are used on a regular basis. The largest cannula that I possess, an anachronistic 4-mm ID lamprey cannula, is used on less than 1% of patients.

The standard configuration of the microcannula tip has two in-line oblong openings. Different and perhaps more efficient microcannula tips are available.

Advantages of Microcannulas

Microcannulas are necessary for optimal results with tumescent liposuction. Among the many advantages of microcannulas are the following.

Less Pain

Microcannulas are less painful than larger cannulas. Obviously minimizing pain is an important component of the technique that enables liposuction totally by local anesthesia.

More Accuracy

Microcannulas are more accurate, and reduce the risk of liposuction-induced irregularities of the skin. Upon changing the direction of a cannula, a larger cannula is more likely to follow a path of least resistance, and be inadvertently advanced along an existing tunnel. A smaller cannula, by being more easily advanced through fibrous tissue, is less likely to deviate from its intended direction. A microcannula reduces the risk of liposuction along an unintended path and produces smoother results.

Greater Finesse

By removing smaller volumes of fat per stroke, microcannulas provide greater assurance against too much fat being removed inadvertently. Proper technique using microcannulas minimizes the risk of irregularities of the skin after liposuction of areas where there is little room for error such as jowls, cheeks, and naso-labial fat pad, medial thighs, and the buttock.

Superficial Liposuction

The superior accuracy in directing the cannula and the more delicate control of fat removal permit a more uniform and smoother results This ability enables a more aggressive and thorough superficial removal of fat and concomitantly minimized risks of irregularities. Superficial, liposuction requires the use of both small cannulas, and the tumescent technique.

More Complete Removal

An increased confidence in achieving uniformly smoother results permits more aggressive liposuction and removal of larger amounts of fat. Thus more fat can be removed using microcannulas than can be removed with larger cannulas. Assuming the results of liposuction are smooth and uniform, patient satisfaction usually directly correlated with the amount of fat removed.

Easier Penetration

Microcannulas can penetrate fibrous fatty tissue with minimal force, thus permitting liposuction of areas that are nearly impossible to treat adequately with larger cannulas. Examples are the

glandular tissue of male breasts, and the dorsal-lateral fat pads just below the bra strap on women, and areas previously treated by liposuction.

Smaller Incisions

Microcannulas require only 2-4 mm incisions and yield scars so small that they are eventually imperceptible. This permits the use of numerous incisions, placed almost anywhere, allowing greater accessibility to all subcutaneous fatty compartments.

No Sutures

Small incisions without sutures heal better with smaller scars. Omitting sutures also saves time, and postpones the first follow-up visit for 4-6 weeks postoperatively..

Accelerated Healing

Multiple incisions without sutures accelerate drainage, which reduces bruising, swelling, and soreness. Wounds within fat created by microcannulas are narrow tunnels that heal more rapidly than larger tunnels. The greater net surface area of the walls of these "microtunnels" promote more rapid absorption of residual fluid within the subcutaneous space. The net effect is greatly accelerated healing.

Greater Efficiency

More rapid return to normal activities, with fewer post-operative problems and patient worries, leads to dramatically decreased need for immediate follow-up visits. This saves huge amount of time for the patient and surgeon (Figure 2). – not included in this doc

Less Elbow Trauma

The resistance encountered when advancing a cannula through subcutaneous fat is minimized by using microcannulas . This is a great advantage in terms of protecting the surgeon's elbow from the chronic stress and trauma of performing thousands of liposuction surgeries.

Using Microcannulas

Microcannulas are fragile and cannot be sued as roughly as larger instruments. Microcannulas are easily bent if used as levers within fatty tissue. The direction of the microcannulas cannot be changed while deep within fat. A delicate touch, and a straight "in-and-out" piston-like motion is required.

When one begins infiltrating a new area with anesthetic solution, the initial infiltration should be within the deepest portion of the targeted fatty compartment, with subsequent infiltration done more superficially. Once a plane within the fat is made tumescent, infiltrating more deeply is difficult because of the inability to precisely palpate the location of the fat-muscle fascia interface.

Similarly, for initial stages of liposuction, it is important to initially direct the cannula as deeply within the fat as permitted by common sense clinical judgment and safety. Fourteen-gauge microcannulas are ideal for infiltrating liposuction in a new area. A small cross section produces less discomfort, less resistance, and more accuracy than larger cannulas.

The 14-gauge microcannulas are used to fenestrate the dense fibrous septa and create small tunnels distributed throughout all the targeted fat. After first using 14-gauge microcannulas, it is easier to use the larger 12- and 10-gauge cannulas. The 14- and 12-gauge cannulas are the work horses, and generally remove the greatest proportion of the fat. The 10-gauge cannula is used the least frequently. Its principle use is to remove any residual fat whenever that appears to be resistant to removal by smaller cannulas. Using microcannulas takes a little more time, but the clinical results are far superior to those achieved using larger cannulas.

Although time efficiency is important, the goal is not how fast the fat is removed, but how smoothly and completely fat is removed. I have found that the extra time needed to use microcannulas is actually more time efficient. The use of microcannulas results in higher patient satisfaction and a lower incidence (less than 3%) of secondary "touch-up" procedures. If you don't have time to do it right the first time, when will you have time to do it right the second time?

Optimal use of microcannulas requires multiple incisions. A small area usually requires four to six incisions, while a large abdomen might have 48 or more.

The cannulas should be advanced through the fat following a fan-like pattern with tunnels radiating from each of the multiple small incisions. Adjacent patterns overlap in a shingle-like fashion and interdigitate on all levels throughout the fat.

The cannula is repeatedly moved from one incision to another, doing a relatively few strokes and just a limited volume of liposuction through any one incision before moving on to another incision. This insures that the reduction is done decrementally, diffusing, and uniformly throughout the entire targeted area fatty compartment. If a large amount of fat were to be removed through one incision before doing liposuction via an adjacent incision, there would be a significant increased risk of postsurgical irregularities of the skin. It is this repeated switching from one incision to another that makes the use of a liposuction pump somewhat more efficient than a hand-held syringe technique.

Microcannula Handle

When an electric-powered vacuum pump is used for liposuction , the microcannula is attached to a handle, which in turn is attached to suction tubing leading to the vacuum pump. This microcannula handle preferably has a thumb-controlled hole or air vent on the handle's side such that the vacuum is maintained while the thumb covers the hole, but the vacuum disappears when the thumb is lifted from the cannula handle.

With the thumb lifted and no vacuum in the cannula, the resistance against the cannula is dramatically reduced as it is advance through subcutaneous fatty tissues. While the microcannula encounters a seemingly impenetrable fibrous partition within adipose tissue, simply opening the air vent by lifting the thumb is often all that is necessary to advance the cannula. Decreased resistance allows manipulation of the microcannulas with more finesse and better control. This fine control is especially helpful for moderating the suction during facial liposuction when advancing through areas where suction is not desired.

Tumescent Liposuction (TLG) Garments[TM]

Using microcannulas and multiple incisions without sutures yields better aesthetic results, more rapid healing, less swelling, less soreness, and less bruising. But open incision sites and encouraging drainage also creates a messy problem of managing the copious drainage of blood-tinged anesthetic solution. This necessitates the need for specially-designed postoperative dressings and garments. Such dressings must comfortably control the voluminous drainage, and be easily changed and managed by the patient. Because of hastened healing, postoperative Tumescent Liposuction (TLG) Garments[TM] (JK Surgical, Inc. San Juan Capistrano, CA) need only be used 4-6 days instead of the usual 2-6 weeks of compression required with the use of larger cannulas.

The Future

As a novel mode of drug delivery we may anticipate many innovative uses of the tumescent technique. There are potential therapeutic applications of tumescent drug delivery to clinical problems far beyond the current limits of anesthesia for dermatologic surgery. I believe that the tumescent technique will prove useful for the lymphatic delivery of chemotherapeutic agents in the treatment and diagnosis of pathology in the lymphatic system.

Optimizing lymphatic uptake of chemotherapeutic agents for tumor metastases, viral and bacterial infections, and radiocontrast media is a focus of current research.[17] The wall of a terminal lymphatic capillary has an interior layer formed by a single thin endothelial cell and an external basal lamina that is widely fenestrated. Between adjacent endothelial cells there are wide gaps in many places. These holes in the lymphatic capillaries facilitate the uptake of macromolecule, proteins, bacteria, blood cells and tumor cells.[18] Blood capillaries, having continuous basement membranes and relatively right intracellular junctions, resist absorption of large molecules.

The larger the molecular weight of a drug, the greater the proportion of a subcutaneous dose that is absorbed via the lymphatic system.[19] Drugs of large molecular weight or drugs attached to large carrier molecules are thus good candidates for targeted drug delivery to the lymphatics.[20]

Theoretically, the tumescent technique should selectively increase lymphatic delivery of low molecular weight drugs as well as larger molecules such as proteins, particulate drug carriers such as emulsions and liposomes, and polymeric prodrugs.

Prolonged blood capillary vasoconstriction with the tumescent technique should increase the proportion of drug absorbed via lymphatic capillaries. In the case of cytotoxic drugs, tumescent dilution of the drugs should minimize local irritancy or concentration-dependent toxicity. In the case of chemotherapy or immunotherapy of breast cancer and melanoma, the lymphatic drainage of a particular anatomic area can be specifically targeted.

Snake bite treatment is problematic, with few controlled studies to support specific therapies. Snake venom, a complex mixture of many proteins having different toxic actions, is often preferentially absorbed via the lymphatics. A tumescent technique for the subcutaneous injection of antivenin locally or proximal to the bite might promote lymphatic uptake of the antivenin, and allow neutralization of the venom before it reaches the systemic circulation. The concomitant infiltration of vasoconstrictors, local anesthesia, heparin, or anti-inflammatories might be beneficial.

The future of a continuously evolving tumescent technique for liposuction is expansive. What I regarded as the tumescent technique yesterday is not the same today. There will always be room for improvement. With self-satisfied complacency or encrusted orthodoxy, we risk arrested development.

Conclusion

The invention of the tumescent technique was the result of dermatology's preference for local anesthesia. It was achieved by pursuing an unchartered path to an unanticipated destination, guided only by clinical observation, and cautious incremental optimization. With time, the basic principles of the tumescent technique will find applications far beyond dermatology. The range of its applications will depend on the imagination of specialists in other disciplines and the nature of the clinical problems that confront them.

Over the past 25 years the American Society for Dermatologic Surgery has evolved into a leading innovator of advanced techniques for plastic and reconstructive surgery of the skin. Dermatologic surgeons have taught other specialties how to do liposuction more safely and with better aesthetic results.

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