The Tumescent Technique
Anesthesia and Modified Liposuction Technique

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The tumescent technique for liposuction is a new technique that has been developed entirely by dermatologic plastic surgeons. It is a dramatic improvement over the traditional methods that require either general anesthesia or deep intravenous (IV) sedation and narcosis. It is this author's contention that liposuction by local anesthesia is safer than liposuction by general anesthesia. Furthermore, the tumescent technique is associated with less discomfort, allows a more rapid postoperative recovery, and provides better aesthetic results than when liposuction is performed using other anesthetic techniques.

The tumescent technique for local anesthesia permits regional local anesthesia of the skin and subcutaneous tissues by using direct infiltration rather than a proximal nerve block. By using large volumes of a dilute anesthetic solution consisting of lidocaine (0.1% or 0.05%) and epinephrine (1:1,000,000) in physiologic saline, the tumescent technique produces swelling and firmness, or tumescence, of targeted fatty areas.

Anesthesia for liposuction surgery can be accomplished in a number of ways including general anesthesia, regional spinal anesthesia, local anesthesia with either deep IV sedation or nitrous oxide sedation, and simple infiltration local anesthesia without IV sedation or narcotic analgesia.[31]

Most of the methods that use local anesthesia for liposuction rely on the concomitant use of narcotics and deep IV sedation to produce a state of consciousness that is equivalent to that produced by general anesthesia. However, with appropriate instrumentation and surgical method, the tumescent technique permits liposuction of large volumes of fat totally by local anesthesia without IV sedation or narcotic anesthesia. The tumescent technique can also be used with general anesthesia or IV sedation.

Recent clinical studies of the absorption pharmacokinetics of lidocaine with the tumescent technique have shown that peak plasma lidocaine levels occur approximately 12 to 15 hours after beginning the infiltration. This remarkably delayed absorption permits a much higher lidocaine dosage than was previously believed possible. Any reduction in a drug's rate of systemic absorption will reduce magnitude of the drug's peak plasma levels. The safe upper limit for lidocaine dosage using the tumescent technique has been estimated to be 35 mg/kg.[34] This is approximately five times greater than standard lidocaine dosage limitations.[10, 20, 38, 45]

Clinical local anesthesia persists for up to 18 hours, obviating the need for postoperative analgesia. The prolonged and profound anesthesia of skin and subcutaneous tissues that is provided by the tumescent technique is probably a result of exposing sufficient lengths of sensory axons to marginal blocking concentrations of lidocaine.[49]

The infiltration of a large volume of dilute epinephrine assures diffusion throughout the entire targeted area while avoiding tachycardia and hypertension. The associated vasoconstriction is so complete that there is virtually no blood loss with liposuction. The mechanical and pharmacologic properties of the fluid is injected subcutaneously prevent the massive shifts of intravascular fluids which are usually seen when liposuction is done by general anesthesia. With the tumescent technique there is no longer any need to replace significant volumes of IV fluids.

Regional Anesthesia Without Nerve Block

There are two reasons why infiltration with local anesthesia has traditionally been limited to relatively small areas of skin: (1) the stinging pain associated with infiltrating the local anesthesia is not easily tolerated, and (2) published dosage limitations have precluded anesthetizing large areas of skin. These limitations have now been overcome with the recognition that (1) adding sodium bicarbonate in order to neutralize the acidity of commercially available local anesthesia solutions of lidocaine and epinephrine dramatically reduces the usual burning-stinging pain of infiltration,[56] and (2) using dilute solutions of lidocaine with the tumescent technique permits profound anesthesia of very large areas. The tumescent technique permits regional local anesthesia of skin and subcutaneous tissue by direct infiltration rather than by proximal nerve block.

ADVANTAGES OF THE TUMESCENT TECHNIQUE

Minimal Blood Loss

Blood loss with liposuction is minimized by the tumescent technique. The extensive vasoconstriction produced by large volumes of dilute epinephrine 1:1,000,000 produces less than 12 ml of whole blood for each liter of pure fat removed by liposuction.[32] In fact, when the tumescent technique is used, patients will typically lose more blood during phlebotomy for preoperative laboratory studies than during a liposuction procedure that removes more than two liters of pure fat. One week following the liposuction of a liter of fat there is virtually no change in the patient's peripheral venous hematocrit.[33]

Rapid Postoperative Recovery

Because there is so little blood loss, there is usually almost no postoperative bruising. Patients may return to a desk-type job within one to two days following liposuction by local anesthesia with the tumescent technique. Elastic support garments are *required* for only three days postoperatively, and exercising may be cautiously resumed three to four days after surgery. Postoperative recovery is quite uneventful.

Prolonged Local Anesthesia

A remarkable aspect of the tumescent technique is that there is so little postoperative discomfort. Treated areas remain at least partially anesthetized for up to 18 hours after surgery. Thus it is not necessary to use local anesthetics that are longer acting and more cardiotoxic than lidocaine.[18, 41, 50, 58]

After liposuction by the tumescent technique, patients do not require postoperative analgesia. Although some patients do take acetaminophen for soreness, narcotic analgesics are not prescribed.

Improved Aesthetic Results

The tumescent technique minimizes the risks of postoperative irregularities of the skin. With careful and methodical infiltration, one can produce uniform tumescence, avoiding irregularities and distortions. The magnification or enlargement of the targeted fatty compartments and the use of smaller suction cannulas (1.5 mm = 12 gauge and 4.7 mm = 3/16-inch outside diameter) permit liposuction to be done more uniformly and more completely. Because of this "magnification" of subcutaneous fat, focal residual collections of fat are more easily detected and treated before completion of the surgery. These features of the tumescent technique minimize irregularities of the skin, which are more likely to be seen after liposuction when only general anesthesia is used.

Certain areas of the body have traditionally been regarded as areas where it is relatively difficult to achieve good results by liposuction.[28] Areas that are prone to develop postsurgical irregularities of the skin or are otherwise difficult to treat by traditional liposuction methods include the medial proximal thighs, anterior thighs, upper abdomen, calves, and ankles. With the use of the tumescent technique, these areas are routinely treated with excellent results. With traditional liposuction techniques, controlling the direction of the cannula through the soft jelly-like fat of the medial thighs is technically difficult. The mobility of this fatty tissue causes the cannula to travel repeatedly along the same path, predisposing to focally excessive fat removal. However, when this fatty compartment has been made firm and swollen by the tumescent technique, smaller liposuction cannulas can easily be directed to achieve a smooth uniform fat reduction.

Decreased Surgical Risk

Massive shifts of fluid out of the vascular space into the areas traumatized by the liposuction cannula and blood loss, which can require an autologous blood transfusion, are major risk factors in liposuction by general anesthesia.[27]

Blood loss has never been a problem with the tumescent technique. In more than 75 consecutive cases of liposuction using the tumescent technique, the mean blood loss was less than 12 ml of whole blood per liter of pure fax extracted.[32] The amount of pure fat extracted ranged from 200 ml to 3050 ml, with 900 ml the mean volume of extracted fat. The volume of whole blood lost during liposuction ranged from 2.5 ml to 24.9 ml, with 9.7 ml the mean volume of blood lost.

With the tumescent technique only minimal amounts of IV fluids are given, although IV access is always established for the unlikely event that it is necessary to administer emergency medications. The tumescent technique essentially eliminates problems associated with the shift of fluids out of the intravascular space. Direct infiltration of large volumes of physiologic saline into the targeted compartments of fat provides sufficient interstitial pressure to preclude additional fluid shifts out of the vascular space. Since the use of morphine and meperidine was discontinued in 1987, there have been no episodes of orthostatic hypotension, even when 2000 to 3000 ml of pure fat has been extracted.

Decreased Anesthetic Risk

The fact that general anesthesia is the current anesthetic method of choice for liposuction is not proof that it is either the safest method or the method that gives the best aesthetic results. Historically, liposuction was developed by surgeons who preferred general anesthesia over local anesthesia. As a consequence, the vast majority of liposuction surgeries are still performed with the use of general anesthesia. The fact that large volume liposuction can be safely and easily accomplished totally by local anesthesia is not well recognized. In fact, in a recent issue of the *Clinics in Plastic Surgery* devoted to lipoplasty, there was little discussion of anesthesia, and there was no mention of the fact that liposuction by local anesthesia alone is possible.[40]

That general anesthesia is associated with a significant risk of serious complications has been pointed out in a number of recent books.[9, 44] In one study of the mortality associated with general anesthesia, 41 cases of cardiac arrest during surgery were reviewed.[23] More than half of the patients were healthy and were categorized as ASA (American Society of Anesthesiology) class 1. The rest were ASA class 2 or 3, meaning that they had only minimal or moderate underlying poor health. Sixteen of the operations were minor, and 32 were elective. The causes of death were categorized as anesthesia mismanagement in 9, cardiovascular abnormality in 9, hypoxemia in 18, and miscellaneous in 5. The possibility of unexpected fatalities with the use of general anesthesia is a strong argument in favor of using local anesthesia whenever it is clinically feasible.

One of the most reliable studies that compares the difference of risk for general and local anesthesia examined the mortality rates for dental surgery in Great Britain from 1970 to 1979.[13] Of the 120 deaths associated with dental disease or treatment during this 10-year period, 10 cases had local anesthesia, 100 cases had general anesthesia, 6 had neither, and in 4 cases there was insufficient information to yield a conclusion. Considering deaths in which the anesthesia was the sole cause of death in healthy subjects, the mortality rate with general anesthesia among outpatients was 1:337,000. The annual number of administrations of local anesthesia in Great Britain, although unknown, must be many times greater than the use of general anesthesia. Consequently, the risks of local anesthesia in outpatient dental surgery must be significantly less than the risks of general anesthesia.

There have been a number of reported deaths and serious complication associated with liposuction. Although virtually all of these have been associated with some form of general anesthesia, the immediate cause has usually been attributed to infection, penetration of an abdominal viscus, an excessive amount of liposuction, or liposuction in conjunction with another risky procedure such as abdominoplasty.

To the best of this author's knowledge, liposuction totally by local anesthesia has not been associated with any serious complications attributable to the local anesthetic.

TECHNICALITIES OF THE TUMESCENT TECHNIQUE

The tumescent technique has evolved substantially since the method was first published in 1987.[33] The use of an even more dilute lidocaine solution, 0.05% instead of 0.1%, permits greater tumescence with better vasoconstriction and more uniform anesthesia. The addition of sodium bicarbonate to the anesthetic solution minimizes the pain of infiltration.[56] Prior to using sodium bicarbonate in the local anesthetic solution, the stinging-burning pain of infiltration was enough to necessitate the use of IV sedation and narcotic analgesia. With the use of sodium bicarbonate (12.5 mEq/L) to neutralize the pH of the anesthetic solution, the tumescent technique does not require IV sedation or narcotic analgesia (Table1).

Table 1. *Recipe for Tumescent Technique Anesthetic Solutions for Body Liposuction (Lidocaine 0.05%, Epinephrine 1:1,000,000*

Lidocaine	500 mg (50 ml of 1% lidocaine solution)
Epinephrine	1 mg (1 ml of 1:1,000 solution of epinephrine)
Sodium bicarbonate	12.5 mEq (12.5 ml of an 8.4% NaH_2CO_3 solution
Normal saline	1000 ml of 0.9% NcC1 solution

When only one of two body areas are treated by liposuction, usually no sedation is needed. When two or more areas are treated, requiring the patient to remain recumbent for more than two hours, 2.5 mg to 5 mg of midazolam is given intramuscularly with a 30-gauge needle and is repeated in two to three hours if necessary. Certain patients will also be given 25 mg of meperidine (Demerol) intravenously just prior to beginning liposuction of the abdomen.

Because of the minimal blood loss associated with the tumescent technique and because of the large volumes of normal saline infiltrated into fat, routine IV fluid replacement is not necessary.

When the tumescent technique is used for liposuction *totally by local anesthesia*, then both the Klein handle and the Klein needle are used. When the tumescent technique is used for liposuction in conjunction with *general anesthesia*, then only the Klein needle is necessary.

For liposuction totally by anesthesia, the Klein handle is used for the initial infiltration of local anesthetic. It is designed to permit the efficient subcutaneous infiltration of large volumes of a local anesthetic solution while assuring minimal discomfort in patients who are fully awake. When using long thin disposable needles, first a spinal needle (20 gauge, 3.5 inches long) and then an intradiscal needle (18 gauge, 6 inches long) are necessary. The 20-gauge needle is used initially because it causes less discomfort than an 18-gauge needle when passed through unanesthetized tissue. These needles are inserted at sites around the periphery of the targeted fatty compartment either through intact skin or through the incision sites that will be used to insert the liposuction cannula. The sites of needle insertion are initially anesthetized using a 30-gauge needle on a 6-cc syringe to infiltrate a small bleb of the local anesthetic solution intradermally.

The Klein needle consists of a 30-cm-long, 4-mm-outside diameter needle welded to a syringe handle. Because it is blunt-tipped, the Klein needle is less likely than a sharp needle to puncture subjacent fascia. When used for regional local anesthesia without IV sedation, the needle is used for the last stage of the infiltration of the anesthesia solution after using the Klein handle. In an awake patient, the blunt tip will cause discomfort when it encounters an area not previously well anesthetized. Upon detecting an area not adequately anesthetized, the surgeon or anesthesiologist can immediately infiltrate anesthetic exactly where it is needed. When testing for completeness of anesthesia, the Klein needle is an essential part of the tumescent technique for liposuction totally by local anesthesia.

The Klein needle is the only instrument needed when the tumescent technique is used in conjunction with general anesthesia or deep IV sedation. Profound vasoconstriction can be achieved over large areas by systematically passing this blunt-tipped needle throughout the targeted fatty compartment along the same pathways that will be used by the liposuction cannula. The anesthetic solution must be infiltrated carefully and methodically to ensure that no areas are missed and that the tissues are made swollen in a uniform, proportionate fashion.

Uniform infiltration is most easily accomplished by using a grid pattern drawn preoperatively with a felt-tipped pen on the overlying skin. By infiltrating anesthetic solution as the needle is advanced, large volumes can be instilled quickly and uniformly, producing firm tumescence , extensive vasoconstriction, and local anesthesia.

Filling a 60-cc syringe with anesthetic is the first step in using the Klein handle or needle. An IV line is attached to the bottle containing the anesthetic solution. Next, using a Klein connector the IV line is connected to a 60-cc syringe, the IV line flow-regulator clamp is opened, and the syringe plunger is retracted. Once the syringe is full, it is removed from the connector and IV line.

When inserting to 60-cc syringe into the Klein handle, the syringe is turned until it is engaged with the Luer-Lok attachment. After removing the connector from the IV line, the IV line is attached directly to the side-port of the handle, and either a 20-gauge 3.5-inch-long spinal needle or an 18-gauge 6-inch-long intradiscal needle is attached to the end of the handle. Finally the needle is inserted through anesthetized skin into subcutaneous fat, and the infiltration begins.

In certain areas where the adipose tissue is regularly more sensitive, the infiltration must be done more slowly than in other area. Areas that are always rather sensitive include the distal-lateral and posterior thighs, upper abdomen and waist near the costal margin, the periumbilical areas, and the medial knees. Except in these areas, most patients can barely detect any sensation as the anesthetic solution is injected.

If not used carefully, a sharp spinal or intradiscal needle may inadvertently penetrate the tissue underlying the subcutaneous fat. To minimize the risk of puncturing the peritoneum or causing a pneumothorax, one must continuously pay careful attention to the exact location of the needle tip within the subcutaneous fat. The safe use of the Klein handle requires that the surgeon or anesthesiologist palpate the tip of the needle while it is being gently advanced along its intended path. To anesthetize deep tissue planes, the thumb and fingers of one hand gently grasp and elevate the skin and subcutaneous fat while simultaneously palpating the needle tip. At the same time the other hand grips the handle and simultaneously advances the needle and depresses the syringe plunger. Refilling the 60-cc syringe is easily accomplished: without removing the needle from the subcutaneous fat simply open the IV-flow regulator clamp and retract the syringe plunger.

By repeating these maneuvers systemically and directing the needle radically in many directions, large regions of the skin and subcutaneous tissue are efficiently anesthetized and vasconstricted. Well-anesthetized areas are easily recognized visually by the pallor and tactually by both the coolness induced by the vasoconstriction and the firmness of the tumescent technique.

A substantial volume of anesthetic solution must be injected in order to produce tumescence and complete anesthesia of a fatty compartment (Table 2). Postoperatively there is considerable drainage of slightly blood-tinged anesthetic solution. This typically continues for up to 18 hours.

SPECIAL LIPOSUCTION TECHNIQUES

In order to accomplish liposuction surgery over extensive areas without the use of general anesthesia, narcotic analgesia, of IV sedation, the standard liposuction technique must be modified.

Originally the tumescent technique for liposuction surgery used an anesthetic solution containing 0.1% lidocaine (1 gm/L). By using cannulas specifically designed to minimize the discomfort of liposuction, the lidocaine concentration can be reduced to less than 0.05% (500 mg/L).

Table 2: T*ypical Range of Volumes of Dilute Anesthetic Solutions Used with the Tumescent Technique for Infiltration into Various Areas*

Abdomen, upper and lower	(800 to 2000 ml)
Hip (flank, or love handle), each side	(400 to 1000 ml)
Lateral thigh, each side	(500 to 1200 ml)
Anterior thigh, each side	(600 to 1200 ml)
Proximal medial thigh, each side	(250 to 600 ml)
Knee	(200 to 500 ml)
Male breast, each side	(400 to 800 ml)
Submental chin	(100 to 200 ml)

Traditional liposuction techniques with general anesthesia use 6-mm, 8-mm, and even 10-mm cannulas. It is difficult to precisely control the direction of such large cannulas since they tend to track repeatedly along previous paths. This can result in the removal of too much fat along one path. An inadvertent approach too near the skin by a larger cannula is more likely to result in an undesirable cutaneous ripple or depression.

In order to optimize accuracy and minimize discomfort, liposuction is accomplished using a *two-stage microcannula method*. Initially a 12-gauge (1.5 mm) microcannula attached to a Klein microcannula handle is used. Because a 12-gauge cannula penetrates the fibrous septae in adipose tissue with minimal resistance, the cannula's direction and relative distance from skin are controlled more easily. The tunnel pattern produced by a 12-gauge cannula is more precise and evenly distributed. Subsequently a Klein lamprey cannula (4.7 mm = 3/16-inch outside diameter) is used to complete the final stage of liposuction. The 4.7-mm cannula follows the paths already made by the 12-gauge cannula. Approximately 80% of the extracted fat is removed by the larger cannula during the second stage of liposuction.

Smaller cannulas are most suited for liposuction by local anesthesia. Clinical experience indicates that a cannula with a large inside diameter is more likely to cause discomfort during liposuction by local anesthesia than is a smaller cannula. Larger cannulas exert greater traction on fibrous structures within adipose tissue. This may cause pain is tissues located beyond the effects of the local anesthesia.

The use of a 12-gauge cannula is a final test for complete anesthesia. If an incompletely anesthetized area is encountered during liposuction, a 12-gauge cannula causes minimal discomfort compared with the startling sensation that a 4-mm or 5-mm cannula might cause.

By reducing the force needed to breach the fibrous septae permeating fatty tissue, the two-stage microcannula method minimizes both the patient’s discomfort as well as the physical stress on the surgeon's arm.

Ancillary Aspects of the Tumescent Technique

Certain operating room procedures change as a consequence of patients being awake and conversant throughout a liposuction procedure.

To maintain warmth and comfort we routinely drape the patient in terry-cloth towels, preheat the bottle of surgical soap by bathing it in comfortably hot water, use the operating room overhead surgical lighting for additional heating when needed, and ask every patient to bring a pair of warm socks to prevent cold toes.

Tactfully maintaining a patient’s modesty while assiduously preserving asepsis requires a common sense approach to preparing and draping patients.

Liposuction removes only a fraction of the anesthetic solution injected with the tumescent technique. Some of the anesthetic fluid drains out during surgery, requiring the use of numerous gauge sponges to soak up the solution. Following surgery there will be drainage of blood-tinged anesthetic solution from the small (3-mm to 5-mm) incision sites used by the cannulas. Bulky gauze sponges are routinely placed under the postoperative elastic support garment. When there is voluminous drainage it may be necessary for the patient to change gauzes several times over the first 12 to 16 hours postoperatively. Warning patients to expect copious postoperative drainage of a blood-tinged anesthetic solution, containing less than 2% whole blood, will mitigate their anxieties. The patient’s attitude toward this drainage becomes more positive when it is understood that maximizing drainage will minimize postoperative bruising.

Relaxing, soothing music should be played in the operating room during surgery. Patients are invited to bring their own favorite relaxing music. During the procedure we either listen to the music or converse casually with the patient. By gently holding the patient’s arm, a nurse can significantly reduce a patient’s anxiety. Skill in these forms of vocal and tactile anesthesia is most beneficial.

When liposuction is planned for multiple areas, the duration of the surgery may be greater than the patient's bladder capacity. During a lengthy procedure it is not unusual that the patient and the IV pole must be walked to the restroom. Anticipating such a necessity allows the surgeon to choose a convenient moment to call a "time-out." Once this mission has been accomplished, the patient is escorted back to the operating room, the remaining surgical areas are scrubbed, and the surgery is continued.

Because even mild degrees of urinary retention can cause increased pulse and blood pressure, it is important to give patient's the opportunity to relieve themselves. Offering patients a choice of a bedpan, urinal, or easy access to a toilet is essential when performing prolonged surgical procedures by local anesthesia. As more advanced dermatologic surgical procedures are accomplished totally by local anesthesia, the advantages of having a patient toilet readily assessable from the operating room will become more widely appreciated.

Using only local anesthetics and eschewing potent respiratory depressant sedatives and narcotics dramatically reduce postoperative recovery time. With the use of the tumescent technique for liposuction totally by local anesthesia, a patient is ready to be discharged home as soon as the elastic support garment is in place and the patient is dressed. Although patients will typically sleep for several hours after returning home, they are encouraged to be as active as they find comfortable, beginning the same day as surgery.

Because of the nausea associated with narcotics, the only postoperative analgesia used is acetaminophen. However, because of the prolonged local anesthesia associated with the tumescent technique, most patients do not take any analgesics postoperatively.

Maximum Safe Lidocaine Dose

Clinical experience with liposuction by local anesthesia has shown that it is safe to exceed the traditional recommended maximum dose of 7 mg/kg of lidocaine and epinephrine. The facile pharmacologic explanation for the safety of using very large doses of lidocaine during liposuction is that a significant amount of lidocaine is removed along with the aspirated fat.[1, 25] However, this assertion has never been documented scientifically.

Maximum safe dose of lidocaine for subcutaneous infiltration is dependent on local tissue vascularity. For infiltration into subcutaneous fat which is relatively avascular, surprisingly high doses are safe. An estimate of a safe lidocaine dose with the tumescent technique for liposuction is 35 mg/kg. When infiltrated slowly and as a dilute solution, this dose should correspond to a peak lidocaine plasma level of between 3 and 4 ųg/ml. This is five times the maximum recommended safe dose for local anesthesia listed in the Xylociane (lidocaine) package insert. Although still higher doses might be safe, such safety has not been documented. In one report of liposuction by the tumescent technique, doses as high as 90 mg/kg were used without serious toxicity.[37]

The peak plasma lidocaine levels are not dramatically reduced by liposuction. It is important to recognize that the removal of lidocaine by liposuction does not dramatically reduce the risk of lidocaine toxicity. It is the inherent slow rate of absorption from fat that accounts for the safety of liposuction by local anesthesia using high doses of lidocaine.

Absorption Rate of Subcutaneous Lidocaine

The finding that peak plasma lidocaine levels with the tumescent technique are delayed for 10 to 14 hours is unprecendented and contrary to accepted dogma. The explanation for such a discrepancy is not obvious. Factors that contribute to delayed absorption include (1) using a dilute lidocaine solution, (2) infiltrating slowly, (3) using epinephrine, and (4) having the site infiltration be relatively avascular tissue.

The current literature substantiates the finding that peak plasma lidocaine levels occur within 60 minutes of giving the dose. This is thought to be valid in healthy patients irrespective of the mode of injection, whether it is given by bolus intravenous infusion; intravenous regional analgesic[26]; intramuscular injection[11,51]; caudal, epidural, intercostal, and peripheral nerve blocks[6, 7, 19, 29, 48, 63];paracervical infiltration[4]; or oral administration.

There are few detailed studies of absorption kinetics of lidocaine infiltrated subcutaneously. For subcutaneous infiltration the peak plasma lidocaine level is usually less than 60 minutes.[36, 52, 54, 57]. An average peak plasma lidocaine level occurring at 62 minutes (range: 30 to 120 minutes) is one of the longest delays documented in the literature.[42] When 2% lidocaine with epinephrine 1:2000,000 was infiltrated into the scalp for hair transplantation, peak plasma lidocaine concentration occurred 45 minutes after the initial infiltration in six of six patients.[39]

The dilution of lidocaine is an important determinant of the absorption rate. As is apparent from the following clinical study, in which there was no liposuction, dilution both delays and diminishes the magnitude of peak plasma lidocaine levels following subcutaneous infiltration. When 1 gm of 0.1% lidocaine with epinephrine 1:1000,000 was infiltrated into subcutaneous fat of the thighs, the peak plasma lidocaine level was 1.2 ųg/ml and occurred 14 hours after beginning of infiltration. Repeating the procedure in the same patient, but using a 10-fold increase in the concentration of lidocaine and epinephrine (1 gm of 1% lidocaine with epinephrine 1:100,000), the peak plasma lidocaine level was 1.5 ųg/ml and occurred approximately 9.5 hours after beginning the infiltration. This is contrary to the observation that lidocaine absorption rates are independent of lidocaine concentration for intramuscular and peridural injections over a concentration range of 1% to 10% lidocaine.[15]

The rate of subcutaneous infiltration is also an important variable for lidocaine absorption rate. Rapid delivery of lidocaine leads to rapid systemic absorption and increased risk of toxicity.[53] When 1% lidocaine in a dose of 1 gm is infiltrated slowly in subcutaneous fat over 45 minutes, the peak level was 1.5 ųg/ml and occurred at 9.5 hours.[34] When similar doses are infiltrated rapidly within a few minutes, peak levels occur within 15 minutes and reach potentially toxic concentration at over 5 ųg/ml.[46]

The site of infiltration is also a factor in lidocaine absorption kinetics. When dilute lidocaine is infiltrated into the subcutaneous tissues of the face, peak lidocaine levels occur within 4 to 5 hours of the infiltration. For facelift surgery using the tumescent technique without narcotic analgesic or IV sedation, the anesthetic solution consists of 0.18% lidocaine and epinephrine 1:563,500 (50 ml of 1% lidocaine, 1 ml of epinephrine 1:1000, 12.5 ml of 8.4% sodium bicarbonate, in 500 ml of physiologic saline). The typical facelift, including submental liposuction, requires approximately 350 ml of this anesthetic solution. In this setting, typical peak plasma lidocaine levels are approximately 0.6 ųg/ml.

Lidocaine Toxicity

Although the risk of lidocaine is minimized by using the tumescent technique, a thorough knowledge of lidocaine toxicology is essential for any surgeon making extensive use of local anesthesia. Lidocaine toxicity is closely correlated with lidocaine plasma levels. Therapeutic plasma lidocaine levels for suppressing ventricular ectopy in the clinical setting of acute myocardial ischemia range between 1 and 5 ųg/ml. Subjective side effects are usually noticed at between 3 and 6 ųg/mg, with objective undesirable side effects, or toxicity, becoming apparent at plasma levels above 5 and 9 ųg/ml.[2] Potentially fatal lidocaine toxicity may occur at plasma lidocaine concentrations as low as 9 ųg/ml (Table 3).

Lidocaine toxicity may result from (1) an overdose, (2) an excessively rapid systemic uptake of an otherwise safe does, (3) impaired hepatic metabolic, or (4) drug interactions.[34]

Table 3. *Lidocaine Levels and Toxicity*

3-6 ųg/ml	Subjective toxicity Lightheadedness, euphoria, digital and circumoral paresthesias, restlessness, drowsiness,
5-9 ųg/ml	Objective toxicity Nausea, vomiting, tremors, blurred vision, tinnitus, confusion, excitement, psychosis, muscular fasciculations
8-12 ųg/ml	Seizures, cardiorespiratory depression
12 ųg/ml	Coma
20 ųg/ml	Respiratory arrest
26 ųg/ml	Cardiac standstill

These are approximate values abstracted from multiple previously published reports including Binnion PF, et al: Br Med J 3:390-393, 1969. Benowitz NL, Meister W.: Clinical pharmacokinetics of lidocaine. Clin Pharmacokinet 3:177-201, 1978; Mather LE, Cousins MJ: Local anesthetics and their current clinical use. Drugs 18:185-205, 1979

Overdose

An overdose occurs when too much drug (More than a safe amount for a given clinical situation) is given as the result of carelessness or ignorance.

Rapid Systemic Uptake

Excessively rapid subcutaneous infiltration of an otherwise safe dose of lidocaine may be a common cause of toxic plasma lidocaine concentrations. Lidocaine is a capillary vasodilator with a rapid onset of action.[14] Epinephrine is a vasoconstrictor with maximum clinical effect delayed approximately 10 to 15 minutes after a rapid injection of a lidocaine and epinephrine solution, systemic lidocaine absorption will be rapid until the epinephrine-induced vasoconstriction has had sufficient time to occur.

Impaired Lidocaine Metabolism

Diseases or drugs that decrease lidocaine metabolism are important causes of lidocaine toxicity. Diseases causing decreased hepatic metabolism can significantly delay elimination of lidocaine from the systemic circulation. Disease of the liver parenchyma decreases lidocaine metabolism directly.[55,59] Other diseases that diminish hepatic perfusion, such as heart disease,[47,60] or diseases associated with hypotension,[21] decrease lidocaine metabolism indirectly.

Drug Interaction

Drugs that decrease hepatic blood flow otherwise decrease lidocaine metabolism can lead to toxic accumulations of lidocaine. Drugs commonly associated with such adverse interactions include cimetidine,[22,35] beta-adrenergic receptor blockers,[8,12,43,62] and procainamide,[30].

Other forms of drug interaction, not necessarily related to lidocaine metabolism, may predispose to severe toxicity. Diazepam (Valium) and other benzodiazepines reduce the risk of seizures associated with excessive plasma lidocaine concentrations[16,17] However, with either diazepam (Valium) or midazolam (Versed) premedication, the first sign of local anesthetic toxicity may be cardiovascular collapse with a significantly decreased chance of successful resuscitation.[3] Diazepam (Valium) may significantly increase the incidence of malignant arrhythmias induced by local anesthetics.[24] The benzodiazepine midazolam reduces the incidence of lidocaine-induced convulsions but has no significant effect on mortality in rats.[61]

SUMMARY

Using the tumescent technique, liposuction can remove large volumes of fat with minimal blood loss. A maximal safe dosage of dilute lidocaine using the tumescent technique is estimated to be 35 mg/kg.

The slow infiltration of a local anesthetic solution of lidocaine and epinephrine minimizes the rate of systemic absorption and reduces the potential for toxicity. Dilution of lidocaine (0.05% or 0.1%) and epinephrine (1:100,000) further delays absorption of peak plasma lidocaine concentrations. Using the tumescent technique for liposuction, peak plasma lidocaine levels occur 12 hours after the initial injection. Clinically significant local anesthesia persists for up to 18 hours. For liposuction, it is not necessary to use local anesthetics, which are longer acting and potentially more cardiotoxic than lidocaine.

References

1. Asken S: Liposuction Surgery and Antilogous Fat Transplantation. East Norwalk, Appleton & Lange, 1988, p 63

2. Benowitz NL, Meister W: Clinical pharmacokinetics of lidocaine . Clin Pharmacokinet 3:177-201, 1978

3. Bernards CM, Carpenter RL, Rupp SM, et al: Effect of midazolam and diazepam (Valium) premedication on central nervous system and cardiovascular toxicity of bupivacaine in pigs. Anesthesiology 70:318-323, 1989

4. Blanco LJ, Reid PR, King TM: Plasma lidocaine levels following paracervical infiltration for aspiration absorption. Obstet Gynecol 60:506-508, 1982

5. Boyes RN, Scott DB, Jebson PJ, et al: Pharmacokinetics of lidocaine in man. Clin Pharmacol Ther 12:105-116, 1971

6. Braid DP, Scott DB: Dosage of lignocaine in epidural block in relation to toxicity. Br J Anaesth 38:596-602, 1966.

7. Braid DP, Scott DB: The systemic absorption of local analgesic drugs. Br J Anaesth 37:394-404, 1965.

8. Branch RA, Shand DS, Wilkinson GR, Nies AS: The reduction of lidocaine clearance by dl propranolol: An example of hemodynamic drug interaction. J Pharmacol Exp Ther 184:515-519, 1973.

9. Brown DL (ed): Risks and Outcome of Anesthesia. Philadelphia, JB Lippincott Co., 1988

10. Carrron H, Korbon G, Rowlingston J: Regional Anesthesia: Techniques and Clinical Applications, Orlando, Grune and Stratton, 1984, p 5

11. Collinsworth KA, Kalman SM, Harrison DC: The clinical pharmacology of lidocaine as an antiarrhythimic drug. Circulation 50:1217-1230, 1974

12. Conrad, KA, Byers JM III, Finley PR, Burnham L: Lidocaine elimination: Effects of metoprolol and of propranolol. Clin Pharmacol Ther 33:133-138, 1983

13. Coplans MP, Curson I: Deaths associated with dentistry. Br Dent J 153:357-362, 1982

14. Covino BG, Vassallo HG: Local Anesthetics: Mechanisms of Action and Clinical Use. New York, Grune and Stratton, 1976, pp105-106

15. de Jong RH: Local Anesthetics, 2nd ed. Springfield, IL Charles C Thomas, 1977, pp 187-188

16. de Jong RH: Toxic effects of local anesthetics. JAMA 239:1166-1168, 1978

17. de Jong RH: Heavner, JE: Convulsions induced by local anesthetic: Time course of diazepam prophylaxis. Can Anaesth Soc J 21:153-158, 1974

18. de Jong RH, Ronfield RA, DeRose RA: Cardiovascular effects of convulsant and supraconvulsant doses of amide local anesthetics. Anesth Analg 61:3-9, 1982

19. Ecoffey C, Desparment A, Berdeaux, A, et al: Pharmacokinetics of lignocaine in children following caudal anesthesia. Br J Anaesth 56:1399-1402, 1984

20. Eriksson E: Illustrated Handbook in Local Anesthesia, 2nd ed. London, Lloyd-Luke, 1979, p 12

21. Feely J, Wade D, McAllister CB, et al: Effect of hypotension on liver blood flow and lidocaine disposition. N Engl J Med 307:866-869, 1982

22. Feely J, Wilkinson GR, McAllister CB, Wood AJJ: Increased toxicity and reduced clearance of lidocaine by cimetidine. Ann Intern Med 96:592-594, 1982

23. Gordon T. Larson CP Jr, Prestwich R: Unexpected cardiac arrest during anesthesia and surgery: An environmental study. JAMA 236:2758-2760, 1976

24. Gregg RV, Turner PA, Denson DA, et al: Does diazepam really reduce the cardiotoxic effects of intravenous bupivacaine? Anesth Anal 67:9-14, 1988

25. Gumuncio CA, Bennie JB, Fernando B, et al: Plasma lidocaine levels during augmentation mammaplasty and suction-assisted lipectomy. Plast. Resconst Surg 84:624-627, 1989

26. Hargrove RL, Hoyle JR, Parker JBR, et al: Blood lignocaine levels following intravenous regional analgesia. Anesthesia 21:37-41, 1966

27. Hetter GP: Blood and fluid replacement for lipoplasty procedures. Clin Plast Surg 16:245-248, 1989

28. Illouz YG: Refinements of the lipoplasty technique. Clin Plastic Surg 16:217-232, 1989

29. Inoue R, Suganuma T, Echizen H, et al: Plasma concentrations of lidocaine and its principal metabolites during intermittent epidural anesthesia. Anesthesiology 63:304-310, 1985

30. Karlsson E, Collste R, Rowlins MD: Plasma levels of lidocaine during combined treatment with phenytoin and procainamide. Eur J Clin Pharmacol 7:455-459, 1974

31. Klein JA: Anesthesia for liposuction in dermatologic surgery. J Dermatol Surg Oncol 14:1124-1132, 1988

32. Klein JA: Reduced blood loss and optimal fluid balance for liposuction: Infiltration regional anesthesia by the tumescent technique. (in preparation)

33. Klein JA: The tumescent technique for lipo-suction surgery. Am J Cosmet Surg 4:263-267, 1987

34. Klein JA: Tumescent technique for regional anesthesia permits lidocaine doses of 35 mg/kg for liposuction: Peak plasma lidocaine levels are diminished and delayed 12 hours. J Dermatol Surg Oncol 16:248-263, 1990

35. Knapp AB, Maguire W, Keren G, et al: The cimetidine-lidocaine interaction. Ann Intern Med 98:174-177, 1983

36. Kosowsky BD, Shahid IM, Gurinder SG, et al: Effect of local lidocaine anesthesia on ventricular escape intervals during permanent pacemaker implantation in patients with complete heart block. Am J Cardiol 51:101-104, 1983

37. Lillis PJ: Liposuction surgery under local anesthesia: Limited blood loss and minimal lidocaine absorption. J Derm Surg Oncol 14:1145-1148, 1988

38. Malamed SF: Handbook of Local Anesthesia, 2nd ed. St. Louis, C.V. Mosby Co, 1986, p-44

39. Maloney JM, Lertora JJ, Yarborough J, Millikan LE: Plasma concentrations of lidocaine during hair transplantation. J Dermatol Surg Oncol 8:950-954, 1982

40. Mladick RA (ed) Lipoplasty. Clin Plast Surg 16:217-403, 1989.

41. Nancarrow C, Rutten AJ, Runciman WB, et al: Myocardial and cerebral drug concentrations and the mechanisms of death after fatal intravenous doses of lidocaine, bupivacaine, and ropivacaine in the sheep. Anesth Analg 69:276-283, 1989.

42. Nattel S, Rinkenberger RL, Lehrman LL, Zipes DP: Therapeutic blood lidocaine concentrations after local anesthesia for cardiac electrophysiologic studies. N Engl J Med 301:418-420, 1979

43. Ochs HR, Carstens, G, Greenblatt DJ: Reduction in lidocaine clearance during continuous infusion and coadministration of propranolol. N Engl J Med 303:373-376, 1980

44. Orkin FK, Cooperman LH (eds): Complications in Anesthesiology, Philadelphia, JB Lippincott Co, 1983

45. Physician's Desk Reference. Oradell, NJ, Medical Economics Company

46. Piveral K: Systemic lidocaine absorption during liposuction (letter). Plast Rescont Surg 80:643, 1987

47. Prescott LF, Adjepon-Yamoah KK, Talbot RG: Impaired lignocaine metabolism in patients with myocardial infarction and cardiac failure. Br Med J 1:939-941, 1976

48. Raj PP, Rosenblatt R, Miller J, et al: Dynamics of local-anesthetic compounds in regional anesthesia. Anesth Analg 56:110-117, 1977

49. Raymond SA, Steffensen SC, Gugino LD, Strichartz GR: The role of length of nerve exposed to local anesthetics in impulse blocking action. Anesth Analg 68:563-570, 1989

50. Rutten AJ, Nancarrow C, Mather LE, et al: Hemodynamic and central nervous system effects of intravenous bolus doses of lidocaine, bupivacaine, and ropivacaine in sheep. Anesth Analg 68:291-299, 1989

51. Schwartz ML, Meyer MB, Covino BG, et al: Antiarrythmic effectiveness of intramuscular lidocaine: Influence of different injection sites. J Clin Pharmacol 14:77-83, 1974

52. Schwartz ML, Covino BG, Narang RM, et al: Blood levels of lidocaine following subcutaneous administration prior to cardiac catheterization. Am Heart J 88:721-723, 1974

53. Scott BD: Evaluation of clinical tolerance of local anesthetic agents. Br J Anaesth 47:328-333, 1975

54. Scott DB, Jebson PJR, Braid DP, et al: Factors affecting plasma levels of lignocaine and prilocaine. Br J Anaesth 44:1040-1049, 1972

55. Selden R. Sasahara AA: Central nervous system toxicity induced by lidocaine: Report of a case in a patient with liver disease. JAMA 202:908-909, 1967

56. Stewart JH, Cole GW, Klein JA: Neutralized lidocaine with epinephrine for local anesthesia . J Derm Surg Oncol 15:1081-1083, 1989

57. Stoelting RK: Plasma lidocaine concentrations following subcutaneous or submucosal epinephrine-lidocaine injection. Anesth Analg 57:724-726, 1978

58. Tanz, RD, Haskett T, Loehning RW, Fairfax CA: Comparative cardiotoxicity of bupivacaine and lidocaine in the isolated perfused mammalian heart. Anesth Analg 63:549-556, 1984

59. Thomson PD, Melmon KL, Richarson JA, et al: Lidocaine pharmacokinetics in advanced heart failure, liver disease, and renal failure in humans. Ann Intern Med 78:499-508, 1973

60. Thomson PD, Rowland M, Melmon KL: The influence of heart failure, liver disease, and renal failure on the disposition of lidocaine in man. Am Heart J 82:417-421, 1971

61. Torbiner ML, Yagiela JA, Mito RS: Effect of midazolam pretreatment on the intravenous toxicity of lidocaine with and without epinephrine in rats. Anesth Analg 68:744-749, 1989

62. Tucker GT, Bax NDS, Al-Asady S, et al: Effects of β-adrenoceptor antagonists on the pharmacokinetics of lignocaine. Br J Pharmacol 17:21S-28S, 1984

63. Tucker GR, Moore DC, Bridenbaugh PO, et al: Systemic absorption of mepivacaine in commonly used regional block procedures. Anesthesiology 37:277-287, 1972