REVIEW ARTICLE

LIPOSUCTION

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INTRODUCTION

Liposuction is the permanent removal of subcutaneous fat through small skin incisions. Metal cannulas are used to dislodge the fat, which is then aspirated using negative pressure. Since its introduction in the 1970s liposuction has become one of the most popular and fastest growing cosmetic surgical operations available. In the United States 385390 liposuction procedures were reported in 2001, a 118% increase since 1997, making liposuction the most frequently performed aesthetic surgical procedure.[1] In this country the incidence is difficult to ascertain, but is probably several thousand per year. An international survey ranked the UK third in the world for total numbers of aesthetic surgical procedures performed.[2] General anaesthesia is frequently provided for patients undergoing liposuction, particularly for multiple areas or combined procedures. The vast majority of liposuction surgery is performed outside the National Health Service. This means that information regarding surgical and anaesthetic practice in this field is scarce. As the popularity of cosmetic surgery grows there have been concerns raised by the press and professional bodies about sales techniques, standards of care and training of staff in some clinics. Unfortunately, recent measures introduced by the Department of Health are unlikely to be firm enough to effectively regulate standards in private cosmetic surgery.[3-4] The majority of trainee anaesthetists will be unaware of the potential problems associated with liposuction. These include the infiltration of enormous doses of local anaesthetic, complex fluid shifts and rare, but fatal complications such as thromboembolism. The technique of liposuction can also be used for some surgery that is not purely cosmetic, and so may become more frequently seen within the NHS. In this review we will briefly outline the history and surgical techniques of liposuction. Important issues in the care of patients undergoing liposuction will be discussed, including preoperative assessment, use of near-toxic doses of local anaesthetic, and perioperative morbidity and mortality.

HISTORY AND TECHNIQUES

The development of modern liposuction began in the 1970s. A French movie actress asked Dr Illouz to remove a large lipoma from her back without leaving a scar. He thought it over and developed an original method for suctioning the fat away.[5] Earlier attempts to remove fat by suction had used sharp curettes and had unacceptable complication rates. Dr Illouz used prior injection of hypotonic fluid and hyaluronidase to soften the fat prior to aspiration using powerful negative pressure. Blunt cannulas of small diameter were employed to create tunnels through the fat, thus leaving connections between deeper levels and the skin. This 'wet' technique resulted in lower rates of bleeding as compared with the 'dry' technique used previously.[6] Dr Klein, a pharmacologist and dermatological surgeon refined this further by devel-

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oping the 'tumescent' technique. This approach utilises a large volume of very dilute local anaesthetic (0.05-0.1% lidocaine) with adrenaline (1:1000000) to provide anaesthesia and minimise bleeding as well as loosen fat. Several litres of this 'wetting' solution were used, with maximum doses of lidocaine several times greater than normally acceptable. No general anaesthesia was given and minimal complications were reported.[7] This technique has become very popular, often modified by the addition of sedation or general anaesthesia. The exact composition of wetting fluids and ratio of fluid infiltrated to fat aspirated vary. Terms such as 'wet', 'superwet' and 'tumescent' are sometimes used interchangeably to describe different techniques. Although these titles are eye-catching, they can become confusing.[8] Postoperatively patients are required to wear elasticated compression garments for some days to encourage the tissues to assume their new shape. The application of intraoperative ultrasound in an attempt to disrupt fat cells or their connective tissue attachments and assist liposuction is a more recent, but unproven, development.[9] Liposuction is not a procedure traditionally performed by a single speciality of doctors. Dermatologists and plastic surgeons have both contributed to the development of present techniques, with some rivalry between the two groups. The apparent simplicity and safety of liposuction has led to surgery sometimes being performed in 'offices' by non-surgeons with little training. These office facilities may not have satisfactory arrangements for monitoring and the management of complications.[10] Liposuction is not an entirely benign procedure and in recent years there has been some controversy surrounding safety. Guidelines of care during liposuction have recently emerged.[11-12]

PREOPERATIVE ASSESSMENT

The ideal patients for liposuction are within 30% of their ideal body weight with areas of subcutaneous fat that are resistant to conventional means of improvement. Fat cells are thought not to multiply during adulthood. Removal should therefore result in permanent improvement of body contour. The overlying skin must be able to retract sufficiently. Liposuction does not improve the appearance of skin commonly known as cellulite and obviously cannot be used to remove intra-abdominal fat. Patients should be offered lifestyle advice in addition to, or instead of surgery. Liposuction should not be seen as a treatment for obesity, but as a way of improving body contour. Other problems that can be treated by liposuction include gynaecomastia, axillary hyperhidrosis and lymphoedema.[13-15] Patients undergoing liposuction are, by definition, often overweight. Since most patients require general anaesthesia or sedation in addition to the use of local anaesthesia this is of particular importance. Patients with a body mass index of $>30 kg/m^2$ have an approximately fourfold increase in risk of perioperative respiratory complications.[16] Drug doses should be based on an estimate of lean body mass. Infiltration of large doses of lidocaine using a safe dose limit calculated from actual body weight would be unwise in obese patients. Preoperative assessment should specifically identify other problems that necessitate the moderation of lidocaine doses. These include drug interactions (see table 1) and certain medical conditions such as liver or cardiac disease. Drugs with the potential for adverse perioperative effects should be discontinued prior to surgery if possible. A history of predisposing factors for thromboembolism should be sought, as pulmonary embolism is a leading cause of death following liposuction.[17] A history of recurrent thromboembolism, moderate cardiorespiratory disease or other severe systemic disease should be contraindications to liposuction.[12] As with any other preoperative patient assessment, facilities should be available for the performance of necessary investigations.

Table 1: Drugs of importance to liposuction surgery.

Increase risk of lidocaine toxicity	
Propanolol, metoprolol	decrease cardiac output and liver blood flow
General anaesthetic agents	
Cimetidine	inhibits enzymatic metabolism
Midazolam	
Phenytoin	similar membrane-stabilising activity
May potentiate the effects of adrenaline	
Phentermine	appetite suppressant and sympathomimetic
MAOIs and tricyclics	
Cocaine, amphetamines	
Thyroxine	drugs abused to control weight
Beta-blockers	alpha effects of adrenaline may predominate
Ephedrine	contained in decongestants and herbal
medicines	
Others	
Oral contraceptives	increased thromboembolic risk
laxatives and diuretics	may be abused to control weight
May increase risk of surgical complications	
Warfarin, NSAIDs	bleeding and haematoma formation
Steroids	poor wound healing

WETTING SOLUTIONS & LOCAL ANAESTHETIC PHARMACOLOGY

As previously mentioned the tumescent technique involves infiltrating a large volume of dilute local anaesthetic into the area to be treated. The tissues become tense with fluid and this facilitates surgery as well as providing analgesia. Lidocaine is the only recommended local anaesthetic for use during liposuction.[11] Concentrations of lidocaine used are typically 0.05-0.1% with 1 in 1000000 adrenaline. Sodium bicarbonate is added to decrease the pain associated with injection in awake subjects. Raising the pH of the solution will also increase the proportion of non-ionized lipid soluble lidocaine, leading to more rapid entry into nerve cells. Typical recipes for wetting solutions for tumescent liposuction are shown in Table 1. The conventional maximum dose of lidocaine with adrenaline is 7mg/ kg and no more than 500mg total dose. These dosage guidelines are exceeded many times over during liposuction surgery. This is particularly true of large volume liposuction when 1.5- 5 litres of fat may be aspirated necessitating the use of several litres of wetting solution. Current guidelines suggest maximum safe doses of lidocaine ranging from 35mg/ kg to 55mg/ kg during liposuction, equivalent to approximately 2.5-4 litres of 0.1% lidocaine solution for a 70kg patient.[12,11] How can this ever be safe? The answer lies in the pharmacokinetic behaviour of lidocaine with adrenaline and the dilutions used in liposuction. It has long been suggested that conventional maximum recommended doses of local anaesthetic are meaningless without regard to the site of injection.[18] However, personnel involved in the use of unconventional doses must have excellent knowledge of local anaesthetic pharmacology to manage patients safely. Toxicity of local anaesthetic drugs is closely related to their plasma concentration. Signs of lidocaine toxicity appear at around 5mcg/ml with perioral numbness, confusion, agitation and muscle twitching. Grand mal seizures occur at approximately 10mcg/ml and cardiorespiratory depression at higher concentrations.[19] Plasma concentration depends, in turn, upon factors such as site of administration, tissue binding and a balance between the vasoactive properties of lidocaine versus co-administered adrenaline.[20] Subcutaneous fat is of low vascularity compared with sites such the intercostal area or epidural space. Tissue blood flow and therefore lidocaine absorption is further reduced by the addition of adrenaline to the wetting solution. The dilution of lidocaine is important in this respect. Previous research has suggested that the minimum effective concentration of adrenaline is 1 in 200000 when combined with lidocaine.[20] However, the lidocaine used for liposuction is at least ten times more dilute than the conventional 1% or 2% solutions. Thus, it is the relative concentrations of adrenaline and lidocaine that determine whether vasoconstriction or vasodilation occurs. In addition, local anaesthetics have been shown to have a biphasic action on blood vessels that is determined by their concentration. Very dilute lidocaine may in fact cause vasoconstriction rather than vasodi-

lation.[21] Lidocaine is relatively lipid soluble and therefore remains bound in subcutaneous fatty tissue, further slowing its removal by the circulation. Surprisingly, only a small fraction of the total lidocaine dose is removed by suction during the operative procedure and this has little influence on the peak plasma concentration.[22-24] Peak plasma concentration (Cmax) is delayed until many hours after the completion of the procedure. Klein measured plasma concentrations in eight patients after tumescent anaesthesia with doses ranging from 750mg to 2340mg of lidocaine. Cmax occurred 12-14 hours later and ranged from 0.8-2.7mcg/ml, well below toxic plasma levels. This led him to estimate the safe maximum dose of lidocaine to be 35mg/kg for the tumescent technique.[25] Samdal et al used doses of between 1260mg and 2880mg (10.5-34.4mg/kg) of lidocaine in 12 patients.[23] Cmax ranged from 0.9-3.6mcg/ml and occurred at 6-12 hours. Ostad et al evaluated 60 patients using multiple interviews over 24 hours following tumescent anaesthesia and liposuction with mean lidocaine doses of 57mg/kg. In addition, 10 of the patients had plasma levels measured. No evidence of toxicity was found. They concluded that up to 55mg/kg of lidocaine is safe for use in tumescent anaesthesia with liposuction.[24] These studies are limited by the small numbers studied, but indicate demonstrate that large doses of lidocaine used in the tumescent technique are safe for most individuals, probably due to the slow rate of absorption. They also suggest that patients ought to be observed for an extended period postoperatively, until peak plasma levels of local anaesthetic have passed. Lidocaine is metabolised in the liver by the enzyme CYP3A4 to the metabolites monoethylglycylxylidide (MEGX) and glycylxylidide (GX) (Boyes 1975). Little is known about the importance of these metabolites, but it is possible that they might accumulate and contribute to toxicity in lidocaine overdose.[25-26] This enzymatic process is estimated to have a maximum capacity of 250mg of lidocaine per hour and so usually obeys first order kinetics.[10] Liver disease or any other situation that impairs this capacity becomes important when large amounts of drug are presented to the circulation. Since hepatic clearance of lidocaine is high, the rate of lidocaine metabolism is highly dependent on changes in liver blood flow. Disease states such as heart failure result in a prolonged lidocaine half-life,[27] as will hypotension,[28] or any cause of decreased cardiac output. Drugs that decrease liver blood flow such as propanolol are known to decrease lidocaine clearance[29] (see table 2). Cimetidine also decreases lidocaine metabolism.[30] Phenytoin may enhance the toxicity of lidocaine due to their common membrane-stabilising action.[31] Midazolam, a drug often administered as sedation during liposuction, may compete with lidocaine for metabolism by CYP3A4. This, or other reasons for impaired lidocaine metabolism, might lead to saturation of the enzyme as drug levels rise during the hours after surgery. Rapid rise in plasma lidocaine levels would then ensue. Residual sedation and the prevention of seizures by benzodiazepines could result in delayed the diagnosis of lidocaine toxicity until cardiac arrest occurs. This has been proposed as a possible explanation for some liposuction associated deaths.[26]

Total doses of adrenaline can be several milligrams during liposuction. The safe maximum dose of adrenaline used subcutaneously in this dilute form is unknown. Studies have not indicated any clinical adverse effects attributed to adrenaline absorption during liposuction. Burk et al measured serum adrenaline levels after tumescent liposuction and observed patients for signs of toxicity. In the 20 patients studied doses of adrenaline ranged from 4.1 to 10mg. Serum adrenaline concentration peaked at 3 hours and ranged from 3 to 5 times the upper limit of normal. No patients experienced hypertension, tachycardia or arrythmias. The authors concluded that most of the adrenaline must be metabolised locally in the tissues rather than entering the circulation.[32] The use of lidocaine and adrenaline in these doses makes it mandatory that careful crosschecking occurs in the preparation of solutions. Doses of drugs used should be clearly

documented and good communication between surgeon and anaesthetist is essential.[33] Table of composition of wetting solutions. (Table 2)

Table 2: Recipe for tumescent technique anaesthetic solution.

Lidocaine 0.05%, adrenaline 1 in 1000000 (adapted from Klein 1990).

Lidocaine	500mg (50mls of 1% lidocaine)
Adrenaline	1mg (1ml of 1 in 1000 adrenaline)
Sodium bicarbonate	12.5 mmmols (12.5mls of 8.4% sodium bicarbonate)
Normal saline	1000mls

PERIOPERATIVE MANAGEMENT

Proponents of the tumescent technique assert that general anaesthesia or sedation is not necessary.[25] In reality few patients are able to tolerate the discomfort of local anaesthetic infiltration and surgery fully awake. Local anaesthesia alone may be suitable for small areas, but most procedures require general anaesthesia or sedation.[34] A regional anaesthetic such as an epidural is a useful alternative, but the use of additional local anaesthetic must be taken into account. Treatment of large areas, multiple sites or liposuction combined with other procedures such as abdominoplasty may take several hours. Surgery on certain areas, for example, the buttocks may require prone positioning. Efforts should be maintain normothermia, including warming of local anaesthetic solutions. Thromboembolic prophylaxis should also be considered, particularly for patients undergoing lower extremity surgery. Not only does immobility and surgical trauma contribute to risk, but also impaired venous flow due to large volumes of subcutaneous wetting solution and compressive garments worn postoperatively.[17] Pneumatic calf compression devices and graduated elastic stockings are recommended for procedures lasting more than 30 minutes, patients over 40 years of age and those on oral contraceptives. The risk of haematoma formation must be balanced against thrombotic risk when considering heparin use in cosmetic surgery.[35] Fluid therapy during liposuction surgery is not an exact science. The surgical trauma associated with subcutaneous curettage and suctioning of fat can be considered to be similar to an internal burn. A considerable amount of body fluid is likely to be lost into this space intra and postoperatively. Blood loss in contrast to this third space loss is usually minimal. Estimates of blood loss as a percentage of the fluid aspirated during liposuction vary from 20-45% with the dry technique to 1% with the superwet or tumescent techniques.[36] Dolsky using a wet technique with an adrenaline containing solution measured the blood loss to be 18.7% of the aspirate or 51.9mls per 100mls. Samdal et al measured blood loss during a superwet or tumescent technique in which the ratio of wetting solution to aspirate tends to be 1:1 or greater. The mean amount of blood loss was 16.5ml/litre of aspirate.[37] While underestimation of fluid requirements can result in hypovolaemia, over hydration with intravenous in addition to subcutaneous fluid can produce pulmonary oedema.[38] It must be appreciated that 60-70% of subcutaneously administered fluid is actually absorbed rather than being removed along with fat.[10] Guidelines on fluid therapy have been suggested based on a study of 53 patients undergoing liposuction. Four of the patients, who had volumes of of ≥4 litres of fat aspirated, had postoperative hypotensive episodes that responded to intravenous fluid. The authors recommend the use of maintenance intravenous crystalloid in addition to wetting solution when less than 4 litres of fat is aspirated. If larger volume procedures are attempted an additional 0.25mls of intravenous crystalloid should be given per ml of aspirate. They also, quite sensibly, emphasise that good judgement, monitoring and communication are more important than guidelines.[36] Local anaesthetic used in the wetting solution can provide analgesia for up to 18 hours postoperatively.[22] Most patients, however, require some other form of analgesia including parenteral opioids.[36] Elastic garments worn to improve aesthetic result should not be so tight as to impair venous return or respiratory excursion. Many liposuction procedures are performed as day case procedures. Regardless of com-

mercial or other pressures, accepted criteria for discharge should be met.[39] If liposuction volume has exceeded 1500-2000mls, large amounts of lidocaine have been used, or complex fluid shifts are expected to occur then same-day discharge is not safe. Patients should expect soreness and unsightly bruising postoperatively and will need simple analgesics for the first few days after discharge. Swelling subsides and skin retraction occurs slowly over several months until the treated area assumes its final appearance.

HOW SAFE IS LIPOSUCTION?

The majority of patients are satisfied with their new appearance and report improved self esteem.[40] Unfortunately cosmetic surgery is never without risk. Minor complications include contour irregularities, prolonged oedema, parasthesia, haematomas, infection and anaemia. Some of these complications may require secondary surgery. More serious complications are rare, but their exact frequency is very difficult to estimate. Given that liposuction is an elective procedure performed usually for cosmetic reasons on healthy individuals, any incidence of life threatening events is cause for concern. As yet there is no mandatory reporting system for complications related to cosmetic surgery. Doctors involved will tend to underreport adverse events for obvious commercial and legal reasons. The sensitive nature of cosmetic surgery means that patients prefer privacy and often do not consult their general practitioner.[3] Cosmetic surgeons may be from one of several parent specialities or may not have completed an accredited specialist training program. This further compounds the problem of quantifying complication rates and regulating practice. Enthusiasts of the tumescent technique insist that it is extraordinarily safe provided that it is not combined with sedation or general anaesthesia. Their assertion is that not only do sedative agents and anaesthesia carry complications in themselves, but also that their use encourages more aggressive surgery to be attempted.[41] A national survey of American Dermatologic Surgeons reported no serious complications and no blood transfusions or hospital admissions required for 15336 patients. However, out of 1778 surgeons contacted, only 66 provided data.[42] Such reporting bias renders these findings of little value. Numerous reports exist of fatal or life-threatening events associated with liposuction. These include haemorrhage, abdominal perforation, severe sepsis, fat embolism, lidocaine toxicity and abdominal wall necrosis.[43-46,26]

Table 3. Complications of Liposuction

Morbidity	
Non-life threatening:	
Contour irregularities, haematoma, persistent oedema, parasthesias	
Life threatening:	
	hypovolaemia due to third space loss, haemorrhage, sepsis
	pulmonary oedema.
Mortality	
	Thromboembolism
	Abdominal or viscus perforation
	Complications of sedation or anaesthesia
	Fat embolism
	Sepsis including necrotising fasciitis
	Haemorrhage
	Lidocaine toxicity

A series of five liposuction related deaths published by Rao et al included three patients who died following unexplained hypotension, bradycardia and asystole. They postulated that these deaths could be explained by lidocaine toxicity even though the doses of lidocaine used ranged from 10 to 40mg/kg, which is well below the maximum dose recommended by some authors (Rao et al 1999). In another series of three deaths, two were found to be due to fat embolus. The third suffered a cardiac arrhythmia during liposuction in which 8 litres of fluid had been administered with adrenaline. The cause of death was judged to be fluid overload. The large quantity of adrenaline given for the procedure may have been a contributory factor, but this was impossible to prove as adrenaline was also given during resuscitation.[47] A similar problem exists with the interpretation of lidocaine levels in post mortem examinations. A survey of American aesthetic plastic surgeons

in which 917 out of 1200 responded revealed 95 deaths associated with liposuction between 1994 and 1998. The role of lidocaine toxicity as a cause of death could not be ascertained due to lack of post mortem toxicology data. Pulmonary embolism was the major cause of death with abdominal or viscus perforation second. Many of the deaths occurred during the first night after discharge home. These results were used to calculate an alarmingly high mortality rate of about 1 in every 5000 procedures. Risk factors proposed by the authors included the removal of large volumes of fat, multiple procedures and hasty discharge policies. They also suggested the use of massive lidocaine and adrenaline doses as probable risk factors for death although this was not supported by their data.[48]

CONCLUSIONS

Liposuction is a procedure performed almost entirely for cosmetic rather than conventional medical reasons, but despite this it deserves our attention. Public demand for this treatment is increasing. This will be met by a poorly regulated private sector if accredited specialists and their professional bodies do not regard cosmetic surgery as an issue worthy of their attention. There is little published in the medical literature about cosmetic surgery in the UK even though thousands of procedures are performed. All surgery carries some risks, but without more information it is not possible to quantify complication rates associated with liposuction in the UK. However, it does seem to be an inherently safe treatment when performed in moderation. Encouraged by this image of safety, some surgeons have attempted over-ambitious surgery leading to an unacceptable incidence of complications. The British Association of Aesthetic Plastic Surgeons recommend that the maximum amount of fat that can be removed safely is 3 litres (BAAPS). This should ensure that fluid shifts, blood loss, local anaesthetic dose and volume of wetting solution are not excessive. Subsequent treatments, if required, should be after a period of six months. Maximum doses of lidocaine of 35mg/kg or even more suggested by some experts should be interpreted with caution. These doses are based on scientific investigations involving small numbers of individuals. Death due to lidocaine toxicity is difficult to prove and may be the reason for some cases of unexplained cardiovascular collapse. The maximum dose should be tailored to each patient dependent on physical status and concurrent medication and should be kept below 35mg/kg.

Table 4: Guidelines for Liposuction

Patient selection:	
ASA I or II within 30% of ideal body weight	
Contraindications:	History of thromboembolism
	Moderate cardiorespiratory disease
Current medications should be noted and discontinued if necessary	
Volume of fat aspirated <3000mls	
Pneumatic calf compression devices or stockings for cases lasting >30 mins	
Lidocaine dose:	
<35mg/kg or lower depending on physical status and possible drug interactions.	

Successful fluid management requires an appreciation of the pathophysiological consequences of liposuction surgery, clinical judgement and adequate monitoring. This monitoring should extend into the postoperative period and include overnight admission when necessary. Perioperative care must meet the same standards whether provided in the public or private sector.

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