Evidence-Based Abdominoplasty Review With Body Contouring Algorithm

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Continuing Medical Education Article

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Abstract

Abdominal contour deformities are an aesthetic challenge to the plastic surgeon. Patients present with diverse clinical histories, multiple comorbidities, and unique aesthetic demands. Weight loss, previous pregnancy, and aging are 3 principal indications for abdominoplasty. Bariatric surgery has increased demand for body contouring procedures. This heterogeneous patient cohort means a "one-size-fits-all" abdominoplasty is not appropriate. Precise evaluation, evidence-based decision-making, and artistic acumen are required while balancing patient goals with safe, realistic, and long-lasting aesthetic outcomes. This article reviews surgical options for abdominal body contouring, providing an evidence-based treatment algorithm for selecting the appropriate procedure for each patient to maximize clinical and patient reported outcomes.

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LEARNING OBJECTIVES

Upon completion of this educational article, the reader will be able to:

1. Understand, critique, and debate surgical options for abdominal wall contouring.
2. Describe abdominal wall clinical anatomy; perform patient evaluation, selection, and preoperative risk assessment; and improve surgical decision-making and postoperative management.
3. Select the most appropriate body contouring procedure from the abdominoplasty treatment algorithm to act as a decision-making framework to optimize clinical and patient-reported outcomes.

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Aesthetic surgical improvement of the abdominal contour began in the nineteenth century, with the first documented abdominal skin excision performed in 1890 in Paris, France, by Demars and Marx.[1] The term "abdominal lipectomy" was coined in 1899 by Kelly to describe transverse resection of the redundant abdominal pannus,[2] with subsequent modernization in nomenclature to "abdominoplasty." Abdominoplasty is the most frequently performed body contouring surgery and fourth most frequently performed aesthetic surgical procedure in the United States at 164,000 cases per annum.[3]

This article outlines key clinical anatomy, describes an efficient yet exhaustive method of patient assessment, evaluates the abdominoplasty evidence base, and provides

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a decision-making framework for selecting the correct procedure for the correct patient.

ANATOMY OF THE ABDOMINAL WALL

The abdominal wall is a three-dimensional structure with the following tissue types and planes.

Skin

Surface boundary delineations are the costal margin, mid-axillary line, iliac crest, and symphysis pubis. Skin variables include age, body mass index (BMI), weight change, and pregnancy.

Subcutaneous Fat

Two layers of abdominal wall adipose tissue exist, superficial and deep, relative to Scarpa's fascia. The superficial layer contains dense adipose tissue and a robust dual blood supply based on myocutaneous perforators and the subdermal plexus. Contrastingly, the deep layer has a single vascular supply from individual perforators and is therefore more susceptible to ischemia during abdominal flap elevation.

Muscle, Fascia, and Rectus Sheath

Scarpa's fascia defines the superficial facial system, suggested to contain lymphatic channels. Full-thickness tissue resection divides Scarpa's fascia, adipose layers, and lymphatics. Deep to the sub-Scarpa's fat is deep fascia and the 4 paired muscle groups of the anterior abdominal wall: (1) rectus abdominis; (2) external oblique; (3) internal oblique; and (4) transversus abdominis.

Aponeurotic portions of transversus abdominis and the oblique muscles envelop rectus abdominis to form the rectus sheath, separated in the midline by the linea alba. The anterior rectus sheath is anatomically consistent, whereas the posterior rectus sheath differs relative to the arcuate line (midpoint of umbilicus and symphysis pubis). Cranial to the arcuate line, the anterior and posterior sheaths are distinct. Caudal to the arcuate line, the posterior sheath is absent due to internal and transversalis coalescence with external and internal obliques to form the anterior rectus sheath only. Plication of the anterior rectus sheath is frequently performed during abdominoplasty after attenuation from obesity or pregnancy.

Vascularity of the Abdominal Wall

Blood supply and venous drainage of the abdominal wall are important considerations to minimize ischemic complications after abdominoplasty. Huger categorized 3 zones[4] (Figure 1). Abdominal flap viability is maintained from vascular contributions of deep or superficial systems, axial perforators, or choke vessels perfusing adjacent angiosomes.[5] However, flap survival is a binary event. A "tipping point" exists in flap survival when tissue demand exceeds supply. However, with appropriate planning and execution, abdominoplasty results in viable flaps for the majority of patients. Extensive lateral vasculature (based on intercostal, subcostal, and lumbar vessels, with further supply from the deep circumflex iliac artery) results in robust lateral tissue. This is the principle behind the safe execution of Lockwood's high lateral tension abdominoplasty (HLTA) and its modifications.[6,7] Tissue excision and liposuction can therefore be more aggressive in the lateral region compared with the more vulnerable central portion by avoiding "danger zones" (Figure 2).[8]

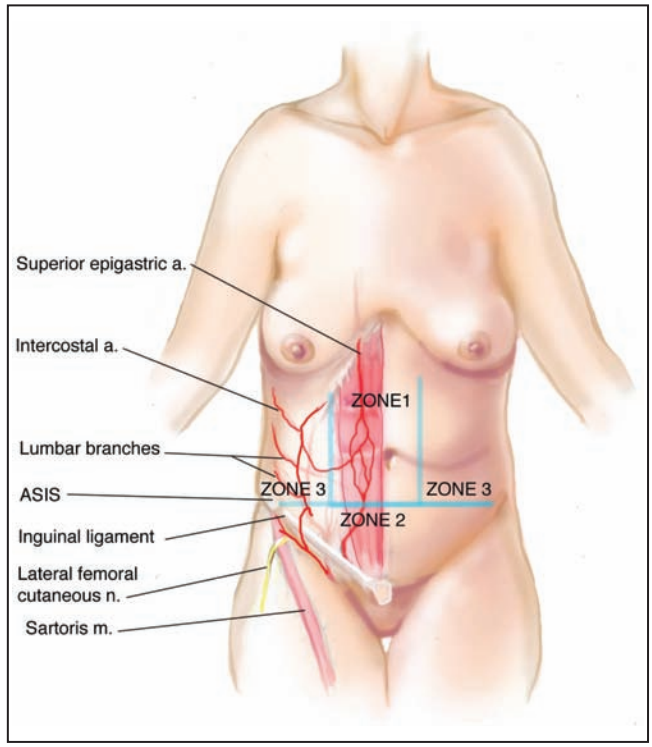

Figure 1. Huger's vascular zones I to III of the abdominal wall. Zone I, superior central portion: Bound by lateral borders of the rectus sheath, costal margin, and a horizontal line drawn between the 2 anterior superior iliac spines (ASIS); supplied by the superior epigastric system, with contributions from the inferior epigastric system. Zone II, inferior portion: caudal to zones I and III; bound by the horizontal line between ASISs, and pubic and inguinal creases; supplied by superficial branches from circumflex iliac, external pudendal, and inferior epigastric vessels. Zone III, superior lateral portions: lateral to zone I; supplied by intercostal, subcostal, lumbar, and deep circumflex iliac vessels.

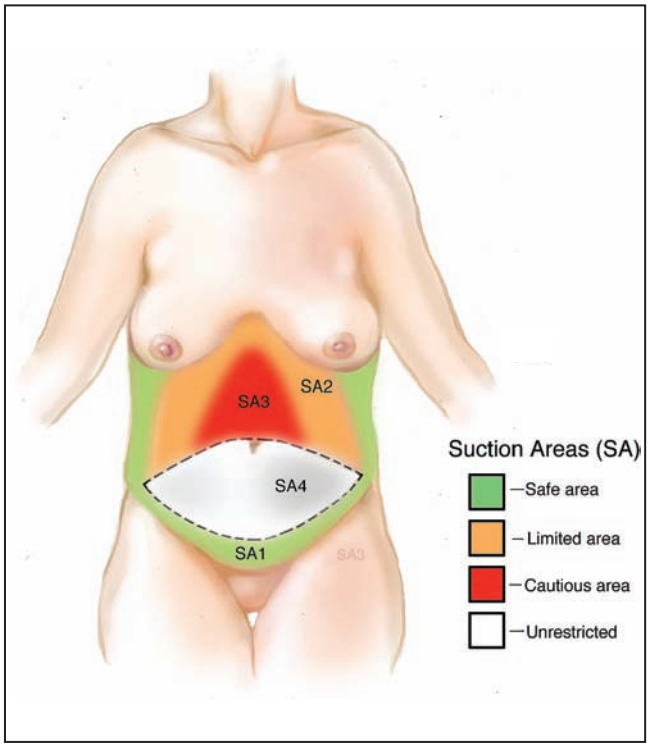

Figure 2. Liposuction danger areas when combined with abdominoplasty.

Umbilicus

The umbilicus is anatomically distinct due to its embryological origins and fetal circulation, with the ligamentous stalk as the obliterated umbilical artery and vein. The deep inferior epigastric artery is the dominant blood supply to the adult umbilicus, with additional subdermal plexus supply. Thinning or rotation of the stalk should be minimized.

Nerves

Anterior and lateral cutaneous intercostal branches of the lower thoracic spine (T7-T12) provide abdominal skin sensation. Anterior cutaneous branches course between transverse and internal oblique muscles entering the posterior rectus sheath lateral to rectus. Lateral cutaneous branches traverse the subcutaneous plane at the midaxillary line. Due to the proximity of the lateral cutaneous nerve to abdominoplasty incisions, 10% of patients experience iatrogenic division of this nerve.[9]

Lymphatics

Debate exists regarding the presence of lymphatic channels within Scarpa's fascia and within a plexus on the surface of the deep fascia on the anterior rectus sheath.[4,10] The abdominal wall caudal to the umbilicus drains into the superficial inguinal nodes, whereas cranial tissue drains into axillary lymph nodes.

Intraabdominal Fat

Fat deposits within the peritoneal cavity affect abdominal aesthetics. Age-associated intraabdominal fat contributes to truncal obesity, typically affecting the anterior abdomen of male patients with increased wound complications.[11,12]

EVALUATION

Patient Consultation

Appropriate patient selection and comprehensive preoperative discussion are important. A focused and thorough preoperative medical history and physical examination identify relevant medical and psychological conditions. All findings should be contemporaneously documented. Specific risk factors include smoking status, diabetes mellitus, autoimmune disease,[13] and previous abdominal surgery (see Clinical Outcomes and Complications below). Past pregnancy and family planning details are important. Comprehensive medication history should be ascertained, including anticoagulants, nonsteroidal anti-inflammatory drugs, contraceptive medications, herbal medications, and allergies. Exhaustive assessment allows patient optimization before surgery and delaying or cancelling surgery if necessary. Psychological screening for body dysmorphic disorder allows surgery to be performed on patients most likely to benefit.

Patient Examination

BMI is particularly relevant in postbariatric patients, with body contouring procedures performed ideally after weight has plateaued. Many surgeons and health-care systems set maximum BMI levels for surgery, given the well-described association between BMI and wound healing and systemic complications. As Gupta et al have shown in their paper, the incidence of complications in an obese patient is increased by at least 3-fold.[14] In our practice, a BMI >30 (obese) is an absolute contraindication to surgery, and BMI 25 to 30 a relative contraindication, where further support to reduce weight is encouraged before surgery.[14,15] Physical examination allows the clinician to "visualize" the abdominal wall and surgical vectors. Indirect assessment of intraabdominal fat should be documented and discussed with the patient to avoid any misconceptions regarding surgical goals. Circumferential visualization of the abdomen is performed with the patient supine, standing, sitting, and in a diver's position to appreciate

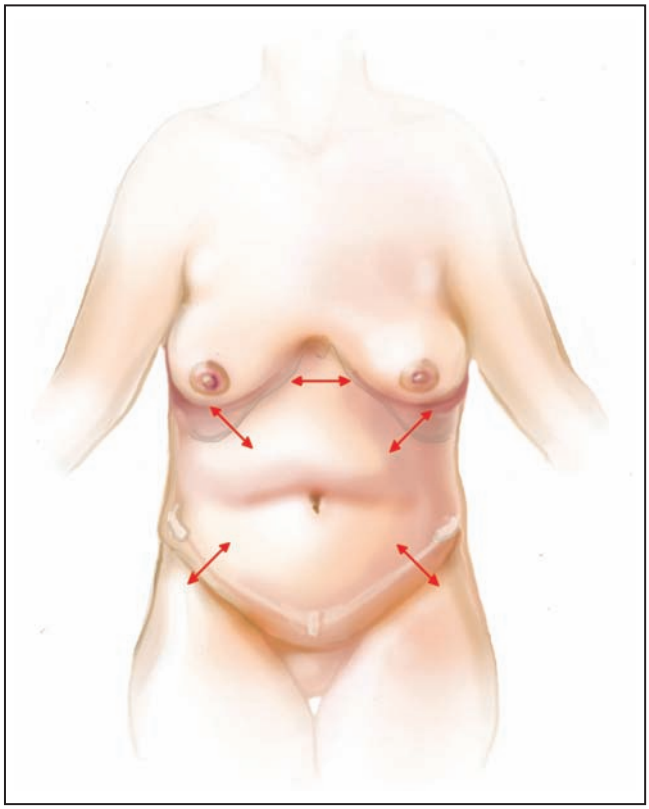

Figure 3. Abdominal pannus vectors. The more a procedure follows the vectors of excess, the more efficient the treatment of redundant skin.

preoperative function, location of incisions, and position of postoperative scars.[7] Anatomical areas assessed are discussed below.

Skin

Redundant anterior skin is common, involving additional horizontal, vertical, or oblique excess. Clinical observations, such as skin mobility and translation of pull, inform surgical planning (Figure 3).[7] The abdominal pannus can be viewed as an aesthetic unit of the trunk, with an appreciation that abdominoplasty results in secondary salutatory changes to the surrounding tissues. Striae are noted and ideally incorporated within excised tissue. However, patients should be advised that striae away from skin incisions will persist and may change in appearance or position. Existing scars, including midline or subcostal, are assessed for integration within the proposed incisions. If this is not possible, scars should be respected by avoidance of complete undermining, given the risk of tissue necrosis. Discontinuous dissection is a safe means of maintaining blood supply to the tissue above (Figure 4).

Bands of Adherence

Adhesional bands exist innately and secondary to previous surgery and cause tissue to resist surgical manipulation as the abdominal wall is redraped during abdominoplasty. Rather than release all adhesional bands at will and jeopardize vital perforators, judicious and conservative release by discontinuous undermining is advised (Figure 4). One may also incorporate adhesional bands within abdominoplasty incisions.

Subcutaneous Fat

Topographical assessment of the subcutaneous fat gives an indication of the thickness of the skin flaps (and variation by location) and anatomical areas amenable to liposuction. Thinner skin flaps typically have better glide, resulting in scar predictability.

Abdominal Protrusion

Objective measures including waist circumference and clothing sizes are recorded in addition to subjective assessment. Protrusion may be secondary to subcutaneous fat, intraabdominal fat, or herniation. Differentiation is imperative. During physical examination, ask the standing patient to relax their abdominal muscles to assess protrusion. Next, ask the patient to maximally retract the abdomen, which helps to assess intraabdominal fat. Another means is to assess the degree of protrusion while the patient lies supine.

Hernia and Rectus Diastasis

All herniations are noted. Preoperative identification allows the surgeon to electively plan repair of the defect. Hernias and rectus diastases can be detected by asking the supine patient to flex at the neck or hip during a straight leg raise. Liposuction should be avoided in areas in proximity to a hernia. Concurrent hernia repair is performed with or without general surgical assistance, at the discretion of the operating surgeon.

Waist Shape

Observe the curvature of the abdomen at the waist. If cuboid or blunted, liposuction is indicated and effective at contouring the waistline.

Informed Consent

Comprehensive informed consent is mandatory, where general and specific complications are discussed. General complications include bleeding, infection, scarring (keloid and hypertrophic), deep vein thrombosis (DVT),

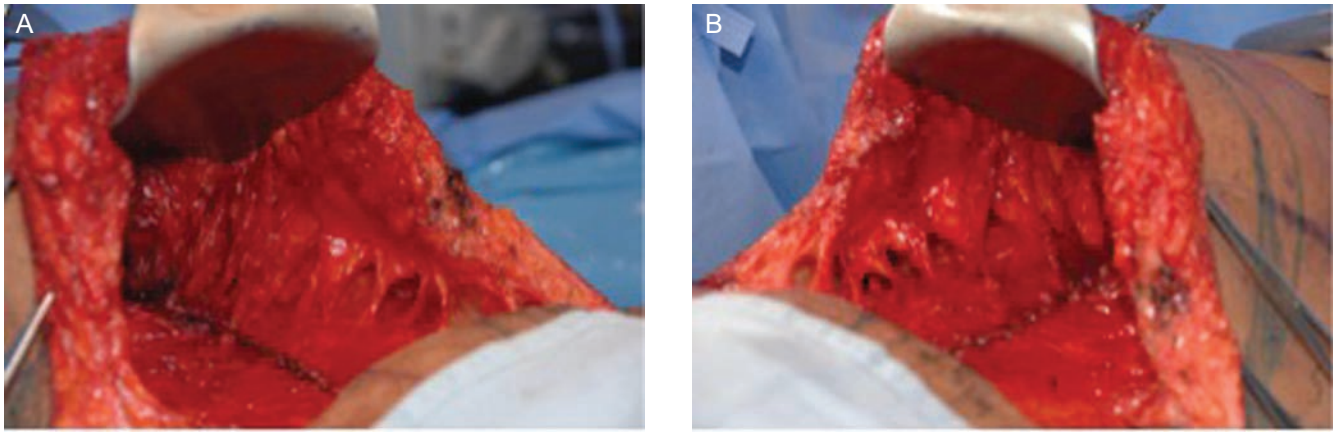

Figure 4. Intraoperative images of this 41-year-old female patient demonstrating discontinuous dissection. (A, B) This critically important maneuver maximizes the number of perforators perfusing the flap to promote primary wound healing at the more vulnerable central aspect.

and pulmonary embolus (PE). Abdominoplasty-specific complications include skin or fat necrosis, delayed healing, wound breakdown, umbilical distortion/malposition/necrosis, asymmetry of the scar or abdominal contour, numbness, seroma, recurrence, and pseudo-recurrence. Limitations of the proposed surgery should be simply explained, detailing excess tissue not addressed by the procedure (including waistline and intraabdominal fat), dog-ears, scar length, position, and permanence. It is advisable to ask patients to wear specific clothing, such as a bathing suit, low-rise jeans, or undergarments, so that scar position can be discussed relative to clothing and lifestyle.

Patient Photography

Photographic documentation—after patient consent—employing standardized protocols is encouraged.[16-18] Complete photographic series support medical records and intraoperative reference and are a visual prompt for patient discussion. Images include the anterior fully exposed patient with arms down and raised in portrait and quarter-turn views, incorporating the operative area and adjacent anatomical zones. In massive weight loss (MWL) patients, imaging all areas of skin laxity comprehensively records all tissue excess. Additional images include sitting straight and in forward flexion to illustrate excess skin often hidden by a protuberant abdomen. Photographs can be taken with the patient holding their excess tissue to demonstrate the potential vector (Supplementary Figure 1, available online at www.aestheticsurgeryjournal.com).

SURGICAL OPTIONS

The goal of abdominoplasty is to comprehensively and safely address the contour deformity with long-lasting results. The extent of the surgery should match the extent of the problem. Assessment of the excess skin vectors permits design of the surgical procedure that will most effectively rejuvenate the abdomen (Figure 3). Techniques are outlined below.

Liposuction Only

Patients with excess subcutaneous fat and minimal skin excess and without herniation are good candidates for liposuction alone.[19] For consistency, the term "liposuction" will be used throughout, instead of the synonymous lipoaspiration, adipoaspiration, and suction abdominoplasty. Illouz, a liposuction pioneer, states that it is "no longer conceivable to aesthetically improve an abdomen without it."[8] However, for patients undergoing abdominoplasty, contention exists as to whether this procedure is more effectively and safely performed concurrently or after abdominoplasty (see Lipoabdominoplasty section below). Lipoaspirate volume is proportional to the risk of postoperative complications (principally seroma), with a suggested maximum volume of lipoaspirate at 100 mL/BMI unit.[20]

Mini-Abdominoplasty

Mini-abdominoplasty addresses modest infra-umbilical skin excess and abdominal wall laxity. Described in 1987 by Greminger[21] and in 1988 by Wilkinson,[22] a small infra-umbilical transverse incision is made to excise excess tissue, with the umbilicus intact or "floating." Midline plication is an optional adjunct and may be partial or total. Potential shortcomings of mini-abdominoplasty include distortion of the umbilicus and lack of addressing the supra-umbilical region.

Full Abdominoplasty ("Traditional Abdominoplasty")

Patients with abdominal wall laxity and vertical skin excess at supra- and infra-umbilical regions are candidates for full abdominoplasty. This technique maximizes surgical exposure to address rectus diastasis or abdominal wall herniation and strengthen the abdominal wall. In contrast to mini-abdominoplasty, full abdominoplasty necessitates more extensive dissection and permits commensurately more skin resection to comprehensively address supra-umbilical excess. Incisions extend across the entire anterior abdominal wall, the rectus sheath is plicated, and the umbilicus can be translocated. Traditional abdominoplasty skin flaps are raised with either complete undermining to xiphisternum or partial undermining of central component.

Rectus sheath plication aims to aesthetically improve and strengthen the abdominal wall.[23-29] Plication techniques vary and include vertical and horizontal orientations employing absorbable and nonabsorbable sutures and single or locaking techniques.[30-33] The repair is planned and marked by opposing the excess tissue and running a suture along the vertical lines to medialize the sheath. The repair is modulated to capture the right amount of fascia to observe the most effective effacement of the laxity without excessive tension.

Technical refinements include Brazilian abdominoplasty, which focuses on achieving a defined waist contour. Flank tightening and waist definition is achieved through medial advancement of Scarpa's fascia after central excision.[34,35] Brazilian abdominoplasty relies on lateral flap excisions down to the Scarpa's fascia only, preserving the deep adipose layer. The central flap is excised full thickness to the sheath. Sutures medialize the Scarpa's fascia onto the linea alba, creating an internal vector to address lateral tissue excess.

Lipoabdominoplasty

Lipoabdominoplasty is the on-table combination of liposuction and abdominoplasty. Advocates favor its single-stage efficiency to safely achieve a smooth abdominal contour.[36-39] Liposuction addresses the potential "step" deformity and theoretically reduces the risk of pseudo-recurrence, where the thicker cranial tissue flap descends caudally over the abdominoplasty scar. Lipoabdominoplasty has been reported as a safe technique provided minimal dissection is performed[36,40] and anatomical "safe zones" are respected (Figure 2).[36,41-46] Type of liposuction is a further variable, because ultrasonic or laser liposuction may increase complications compared with traditional liposuction.[47] If simultaneous liposuction is planned, Dr Simeon Wall's technique of SAFELipo may reduce these risks.[48]

Despite Illouz's support of lipoabdominoplasty in his seminal paper in 1992,[8] caution is advised if liposuction is "used erroneously or excessively by some resulting in unnecessary complications", particularly in patients with high BMI.[8] Complication rates are additive each time liposuction is included as an adjunct procedure to a body contouring procedure.[49] Indeed, members of the ASAPS are divided in opinion on lipoabdominoplasty.[50] The abdominal flap relies on a delicate vascular plexus and is therefore susceptible to iatrogenic trauma from liposuction cannulae. This mechanism is supported by high levels of endothelial cells within lipoaspirate.[51] As encouraged by the senior author, a safer alternative is to plan liposuction as a "second stage" 6 months after abdominoplasty. Delayed targeted liposuction can deliver at once a safe but comprehensive and aggressive fat extraction post-abdominoplasty.[7]

Contemporary evidence exists in support of lipoabdominoplasty. Roostaeian et al employed SPY (LifeCell Corp, Bridgewater, NJ) fluorescent imaging to compare abdominal wall perfusion after lipoabdominoplasty vs traditional abdominoplasty (with full undermining), demonstrating no difference in perfusion or complications.[39] However, this finding is in contrast to the previous research by Mayr et al, who used dynamic laser fluorescence videoangiography (IC-VIEW, Pulsion Medical Systems AG, Munich, Germany) to assess abdominal wall perfusion.[52] No data on traditional abdominoplasty with partial dissection to the central component were included.

On balance, the impasse between lipoabdominoplasty and traditional abdominoplasty mandates caution, especially given the increase in complications of abdominoplasty alone (3.1%) vs lipoabdominoplasty (3.8%), from the national CosmetAssure database of 25,478 abdominoplasties.[49] However, if surgical preference is towards lipoabdominoplasty, it is prudent to minimize (or avoid) central tissue dissection or liposuction and instead perform lateral liposuction only.

High Lateral Tension Abdominoplasty

Lockwood's HLTA is based on the principle that tension and secondary vector generation from abdominoplasty flap closure should be oblique, directed away from the midline and towards the lateral edges, as opposed to the traditional vertical vector (Supplementary Figure 2, available online at www.aestheticsurgeryjournal.com). This "body lifting" effect is ideal after MWL and pregnancy changes including further aesthetic advantages of improving the postero-lateral thigh contour.[6] For the senior author, HLTA comprehensively addresses the entire aesthetic unit of the trunk in a single procedure, generating safe, reliable, and aesthetically pleasing outcomes.[53] And, when indicated,

extending the incisions posteriorly can deliver a rewarding posterior thigh/buttock correction. However, as suggested by Lockwood and more recently by Aly, definitive correction of postero-lateral tissue necessitates a posterior body lift.[54-56]

Despite including "tension" within the nomenclature, it is imperative that tension is directed to underlying fascia rather than the wound edge. Patients should be aware of a longer scar from HLTA compared with the traditional abdominoplasty. Disproportionate skin excess in the superior-lateral aspect of the abdomen mandates discussion with the patient, because conversion to fleur-de-Lys abdominoplasty or second-stage reverse abdominoplasty may be required (see below).

High Superior Tension Abdominoplasty

Extensively published by Louarn and Pascal, high superior tension abdominoplasty directs tension towards the relatively more vascularized periumbilical region compared with the suprapubic region.[57,58] Progressive tension and quilting sutures caudally advance the flap during closure. Umbilical translocation is also performed. These techniques decrease the risk of skin flap necrosis, scar attenuation, and seroma formation by preservation of sub-Scarpa's fat and inguinal and axillary lymphatic channels. Abdominal wall sensation is also preserved.

Fleur-de-Lys Abdominoplasty

Vertical *and* horizontal redundancies in the anterior trunk are comprehensively addressed with a fleur-de-lys abdominoplasty through combining a midline vertical incision with a transverse suprapubic incision (Figure 5).[59] This approach is commonly employed in MWL patients to remove excess tissue in both planes that is beyond the limits of traditional abdominoplasty. A "radicalized" fleur-de-lys abdominoplasty can further assist MWL patients by incorporating existing midline scars from bariatric surgery within the tissue excised, including posterior extensions of the horizontal incisions to give a partial body lift effect,[60] or placing the vertical incision more laterally to excise the scar from a Kocher's incisions.[61] Further adjustments for MWL patients include a more caudal inferior incision to address mons pubis ptosis, excising an inverted "U" at the apex of the vertical incision, and lowering the superior horizontal incision by 2 to 3 cm for tension-free closure.[62] Inverted "Y" variations also address the skin redundancy of MWL patients.[63-66] In addition to recontouring the upper abdomen from direct excision, there is an indirect "corset effect" on the entire trunk, to the posterior midline, due to prodigious tissue removal and commensurate "recruitment" with closure. During layered closure, the umbilicus is inset directly into the vertical incision, and the superficial facial system of the vertical component is reapproximated.

Outcomes after fleur-de-lys abdominoplasty are mixed, with some evidence suggesting comparable complication rates to traditional abdominoplasty[67] yet others reporting increased wound-healing complications and necrosis.[68,69] Favorable outcomes may be more likely after limiting undermining to the tissue to be excised only, thus preserving the full complement of perforators supplying the remaining tissue. Safety results are further enhanced if Lockwood's principles of tension traction and secure wound closure are also applied.[7,53,70]

Specific measures to reduce complications after fleur-de-lys abdominoplasty include: (1) Tailor tack the wound closed first, particularly at the "T" juncture, to maximize skin resection and promote a tension-free wound closure; and (2) extend the epigastric incision high enough to minimize the almost certain dog-ear, but not too high to mar the cleavage region or create a symmastia.[53]

Reverse Abdominoplasty

Described in 1972 by Rebello and Franco,[71,72] reverse abdominoplasty is a stand-alone procedure or second-stage procedure if a previous abdominoplasty technique inadequately corrects residual tissue at the superior abdomen. By observing the vectors of excess, skin redundancy can be propitiously removed (Supplementary Figure 3, available online at www.aestheticsurgeryjournal.com). This approach is particularly relevant in MWL patients with horizontal excess from upper abdominal skin folds and can be combined with reduction mammoplasty with a simple "marriage" of the inframammary incisions.[73] Reverse abdominoplasty is also indicated where skin excess and abdominal protuberance predominantly affects the upper third of the abdomen, where cranial striae can be incorporated in flap excision. Umbilicus elevation can occur, but this effect can be attenuated by not undermining the flap above for several centimeters.[53] And it is best to conduct this abdominoplasty prior to attendant breast surgery so that the inframammary crease may be defined and secured properly. Irrespective of concomitant breast surgery, the sheer heft of the inset abdominal flap can result in deformation of the breast shape or inferior drifting of the scars as tissues relax. The best measure of prevention is to "overengineer" the repair of the abdominal flap to the defined inframammary crease employing an abundance of sutures.

Contemporary Techniques, Treatments, and Technologies

Subtle modifications to established techniques continue to be documented, with many rebranded as novel procedures. For example, "dynamic definition mini-abdominoplasty"

Figure 5. Fleur-de-lys abdominoplasty in this 48-year-old massive weight loss female patient weighing approximately 150 pounds. By "treating" the vectors of excess in this case with perpendicular incisions, the skin excess can be excised most efficiently and the contours realized most effectively. (A) Fleur-de-lys abdominoplasty diagram. (B) Preoperative frontal view. (C) Patient demonstrating expectation of results and surgical confirmation of markings. (D) Postoperative frontal view at 18 months demonstrating global correction of the abdominal deformity by harnessing the multiple vectors of excess as the modus operandi of the fleur-de-lys. Specifically, this approach promises not only a more complete abdominal correction, but of particular note, an impressive "indirect" treatment of the most anterio-lateral thigh and the knee and posterior truncal-buttock deformities. Also, note the subtle quality of the vertical scar. (E) Preoperative and (F) postoperative three-quarter view. (G, H) Demonstration of the dramatic indirect "corset" effect from comprehensive anterior resection on the posterior/back/buttock areas of redundancy (G) before and (H) after fleur-de-lys abdominoplasty.

combines midline incision, abdominal wall plication, and open liposuction after retracting the flap.[74] Wound closure innovations include Insorb (Insorb, Incisive Surgical, Plymouth, MN) absorbable subcuticular staples, Prineo (Ethicon, NJ) dermal mesh, and 2-ocryl cyanoacrylate adhesive as a postoperative "water-tight" barrier.[75-77] Equivalence to intradermal sutures has been demonstrated, with faster execution.[77,78] Barbed sutures, such as V-loc (Covidien, Dublin, Ireland) feature faster closure times,[79,80] and the mechanomodulatory Embrace device (Neodyne Biosciences, CA) has demonstrated reduced scarring.[81-83] Fibrin sealants are another contemporary tool to decrease

Table 1. Abdominoplasty Treatment Algorithm

Excess skin			Adipose tissue		Rectus diastasis	Umbilicus position	Surgical options
Infra-umbilical	Supra-umbilical	Thigh	Subcutaneous	Intraabdominal			
None-min	None-min	N/A	Min-severe	None-severe	Min	N/A	Liposuction
Min	Min	N/A	Min	None	Min	Normal	Tethered umbo w/ mini-abdominoplasty ± fascial repair ± liposuction
Mod	Minimal-mod	N/A	Min	None	Min	High	Floating umbo w/ mini-abdominoplasty ± fascial repair ± liposuction
Mod	Mod-severe	Min-mod	Mod	Mod	Mod	N/A	Translocation umbo w/ "traditional" abdominoplasty w/ fascial repair w/concomitant liposuction or second-stage liposuction
Min	Severe	N/A	Mod	Mod	Mod	Normal-low	Reverse abdominoplasty ± immediate lateral liposuction follow-up liposuction
Mod	Mod-severe	Mod-severe	Mod	Mod	Mod	N/A	HLTA with fascial repair; primary or second-stage liposuction
Severe	Severe	Severe	Mod	Mod	Mod	N/A	Fleur-de-lys abdominoplasty + high tension abdominoplasty with fascial repair and second stage liposuction
Severe	Severe	Severe	Severe	Severe	Severe	N/A	Panniculectomy only or decline surgery

HLTA, Lockwood's high lateral tension abdominoplasty; Min, Minimal; Moderate, Mod; Umbo, Umbilicus; N/A, Not applicable.

seroma rates following abdominoplasty.[84-86] TissuGlu (Cohera Medical, Pittsburg, PA) is a lysine-derived urethane adhesive that received US Food and Drug Administration approval in 2015.[87] Evidence supports a reduction in total drain output after its application to the abdominoplasty wound bed prior to closure.[88]

Summary of Surgical Options

A plethora of techniques exist to address the abdominal contour, each with specific indications. No single best procedure exists, and instead the patient's health, expectations, and anatomy should be considered case by case to select the safest procedure to meet their needs. On some occasions, it is prudent to delay or decline surgery so that complications are reduced or eliminated. The surgeon can follow our treatment algorithm to select the best procedure (Table 1).

SPECIAL CONSIDERATIONS

A number of issues warrant individual consideration before abdominoplasty and are discussed below.

Massive Weight Loss Patients

Gastric bands and similar mechanical interventions to promote satiety are increasing the numbers of MWL patients seeking abdominal contouring surgery. One-third of bariatric surgery patients achieve weight loss conducive to body contouring surgery.[89] Patients with the greatest reduction in BMI post-bariatric surgery require more extensive body contouring techniques.[90] The gastric band inflation port, typically located in the epigastric or subcostal regions, is ideally left in situ during abdominoplasty. However, if the proposed body contouring might impinge on this area, it is prudent to liaise with general surgical colleagues regarding removal.

MWL patients have complex medical, aesthetic, and psychological needs. Complication rates are twice as high in MWL compared with non-MWL patients following traditional abdominoplasty (41-48% vs 22-29%).[91,92] The American Society of Anesthesiologists Physical Status Classification is the most reliable predictor of complication risk,[91] and more conservative tissue resection results in fewer complications.[92] Innate physiological differences in collagen in MWL patients may explain increased wound healing complications.[93] MWL patients' skin demonstrates stronger biomechanical properties during tensiometry than non-MWL controls, with increased epidermal thickness and dermal vascularity but decreased elastin content.[94] These changes are likely to be a secondary response to excessive stretch during extreme weight gain and a loss in tissue "recoil."

MWL patients have specific nutritional needs, associated conditions (dehydration, iron deficiency anemia), gastrointestinal symptoms (reflux, nausea, vomiting), and

pathology (gallstones, "dumping" syndrome from rapid food deposition into the small bowel). Anesthetic concerns arise from excess soft tissue presenting a challenging airway, unpredictable pharmacokinetics and pharmacodynamics, and suboptimal lung function. Preoperative identification of comorbidities before optimization is particularly relevant for this patient cohort.[95]

Umbilicoplasty

Umbilicus aesthetics suggest a position just above the midline (46:54 relative to xiphoid process and lower vulvar cleft), a small size (5% of the above measurement), oval shaped, and without hooding.[96] Many surgeons discourage circular incisions and fascial fixation due to retraction, stenosis, and unsightly scarring.[97] A multiplicity of incisions has been proposed, including star-shaped,[98] V-shaped,[99] and inverted V-shaped.[100] It is the senior author's preference to perform a single vertical slit excision during HLTA cases, and then tailor accordingly to each patient, before skin sutures only.

Mons Pubis

The position and appearance of the mons pubis changes with weight and age. Potential abdominoplasty patients may present with a widened or ptotic mons pubis. Given the consequence of abdominoplasty vectors on mons pubis position, it is imperative to consider mons dynamics when striving for a well-contoured abdomen. Cranial advancement and suturing mons superficial fascia onto rectus fascia results in stable positioning of the mons, with dermal-fascial suspension techniques offering further anchoring.[35,101] Horizontal tissue excess can be excised through a midline vertical wedge resection and vertical excess can be incorporated within the horizontal abdominoplasty flap. The surgeon must resist "recruiting" this vertical pubic excess to close the wound.[35] Mons pubis ptosis has been classified into 4 grades, with combinations of liposuction, fascial-dermal suspension, and wedge excision proposed for optimizing aesthetic outcomes.[101]

Postoperative Care

The patient's bed is put in a lawn chair position to minimize wound tension. Warmth and hydration is maintained. Thromboembolism-deterrent (TED) hose are worn continuously until frequent ambulation is resumed. Drains remain in situ until output decreases to 30 mL over 24 hours after mobilization (typically between postoperatively days 5 and 14). Abdominal pressure garments, such as a Velcro binder, are worn for 2 weeks before switching to a commercial girdle-type compression undergarment for an additional 6 weeks. Multidisciplinary literature suggests pressure garments decrease scar contraction, collagen fiber diameter, and skin hardness while increasing skin strength and maintaining tissue perfusion.[102,103] To ensure the binder is not overly tightened, the surgeon should first apply the garment and draw a line at its limits. Heating pads, hot water bottles, and ice packs are discouraged, because abdominal skin may be insensate. Stool softeners combined with a nutritious, high-fiber diet are recommended.

Analgesia

Appropriate pain management, particularly in the first 48 hours, improves postoperative mobility and physiology, ensuring maximal tidal volumes and minimizing atelectasis. Options include:

- Local infiltration. Bupivacaine is frequently administered, either as Marcaine or the longer acting liposome suspension Exparel (Pacira Pharmaceuticals, NJ), and 2 mg/kg is a recommended maximal dose.
- Regional infusion. Local anesthetic can be administered via a catheter sited intraoperatively on the rectus. Continuous infusion pumps decrease postoperative pain and opiate demand, with earlier ambulation (22 hours vs 41 hours).[104,105] Fixed costs from the device can be negated against reduced analgesic requirements, VTE complications, and length of hospital admission.[106]
- Regional block. Bilateral transversus abdominis plane blocks can be performed under direct vision using a spinal needle[107] to reduce pain and opiate demand and improve ambulation.[108] Though technically challenging in MWL patients,[109] blocks coupled with sedation provide sufficient analgesia for some surgeons to offer outpatient abdominoplasty.[110]
- Epidural. An epidural catheter provides in-patient analgesia for the first postoperative night, which is particularly useful after extensive body contouring surgery.[111] A purely sensory blockade with motor preservation promotes postoperative ambulation to minimize VTE events.[112] A Foley catheter assists with continence and fluid monitoring.

Length of Stay

In-patient stay permits closer monitoring of pain, hydration status, medication compliance, and drain output, with the opportunity for encouraging supervised ambulation. This aims to minimize the risk of VTEs and improve patient comfort. Despite these advantages, increasing literature supports outpatient abdominoplasty.[113-116] However, abdominoplasty has the highest readmission rates of all day-case plastic surgical procedures (1.78%),[117,118] particularly in obese patients.[119]

CLINICAL OUTCOMES AND COMPLICATIONS

In an outcome-driven era, it is imperative to strive for excellence in clinical and patient-reported outcomes. The bar should be set at a zero complication rate. However, even in the best surgical hands, complications occur; the ASAPS reports complication rates after abdominoplasty including necrosis (5.4%), contour irregularity (5%), and hematoma (1.4%).[50] Cumulative data suggest 1 in 3 patients experience at least one minor complication post-abdominoplasty.[52,120] Specific complications are discussed below.

Necrosis

Despite the fact that skin necrosis seemingly occurs at times without attributable cause, steps can be taken to minimize the risk of this complication. If one "pushes the skin envelope" with excessive flap mobilization, resection, undermining, thinning (either by liposuction or excision), manipulation, or tension, the risk of necrosis is increased, particularly in diabetic patients. After abdominoplasty, the abdominal wall has 18% of the vascularity of its untouched preoperative state.[52] Patient risk factors such as diabetes mellitus, smoking, and high BMI further increase the risk of necrosis, and "operative conservatism" should be practiced in such patients. Data on necrosis figures are variable, with reports ranging from 1% to 5.4%.[50,121-124]

Fat necrosis may occur in isolated subcutaneous pockets or as part of a necrotic flap. Incidence is approximately 2% after abdominoplasty,[124] though data are clouded by nonstandardized definitions.[125] Small, discrete, or deep patches of fat necrosis may be asymptomatic, unperceivable, or tolerated. However, extensive necrosis precipitates infection and/or wound breakdown, necessitating surgical exploration and excision.

Seroma

Seroma is the most common complication following abdominoplasty.[12,20,121,126,127] Obesity, extensive dissection, and liposuction are contributing factors.[126,128] Despite this information, lymphatic anatomy of the abdomen is poorly understood, with evidence old and new suggesting anatomical variability.[127,129] Seroma pathogenesis in the abdominoplasty patient is postulated as secondary to surgical division of lymphatic channels. However, the exact depth of lymphatic channels as they course the abdominal wall is contentious, with cadaveric studies postulating infra-umbilical lymphatic channels shift from superficial (dermal) to deep (sub-Scarpa's) during an oblique caudal descent, where the Scarpa's fascia is pierced 2 to 3 cm above the inguinal ligament before draining into the superficial inguinal lymph nodes.

Debate also exists as to the presence (or absence) of connecting channels linking superficial and deep lymphatic channels.[127] A surgical dogma exists suggesting preservation of Scarpa's fascia reduces seroma formation due to the assumption that Scarpa's fascia is anatomically synonymous with lymphatic channels. Indeed, preservation of Scarpa's fascia during abdominoplasty has been quantified as responsible for reducing postoperative seroma formation from 18% to 3%.[130] However, as highlighted by Swanson, with a self-reported seroma rate of 5% despite dividing Scarpa's fascia, the reduction in postoperative incidence may be coincidental rather than causal, with conservative use of electrodissection resulting in a more modest inflammatory response and therefore less seroma.[131] Other series report equivalent seroma rates comparing electrocautery dissection with scalpel dissection but an associated increase in seroma rates during concomitant flank liposuction.[132] Indeed, the definition of seroma is subject to interpretation, with composition representing inflammatory exudate rather than purely lymphatic "leak" from theoretically divided channels.[131,133]

Tissue glide and sheer forces are an alternative seroma hypothesis; evidence suggests minimizing the glide between tissue planes reduces the inflammatory response and therefore reduces seroma formation. An adjunct to this hypothesis is an obliteration of dead space with a more secure "seal" between tissue planes and layered closure of Scarpa's fascia to decrease skin tension, eliminate dead space, and reduce the risk of seroma formation.[7] Avoidance of liposuction is also based on this theory, where it is postulated that the space created by cannulae insertion and aspiration is involved in the pathogenesis. Furthermore, seroma is the number one complication after liposuction, and its occurrence is directly proportional to lipoaspirate volume.[20] Regardless, techniques to anchor tissue planes and obliterate dead space have been advocated though quilting sutures[134] and the eponymous "Pollock's progressive tension sutures,"[135-137] and "Baroudi-type sutures."[138] A meta-analysis supports progressive tension sutures and preservation of Scarpa's fascia but shows clinical benefit of fibrin glue.[139]

Seroma requires percutaneous drainage and regular assessment to reduce the risk of pseudobursa formation. Chronic seromas can be managed with sclerotherapy using bleomycin or doxycycline.[140] If recalcitrant, open pseudobursa excision is usually definitive.

Venous Thromboembolism

Thromboembolic disease is a major healthcare issue with its pathogenesis based on Virchow's Triad (venous stasis, endothelium injury, and blood hypercoagulability).

Opposing efforts should therefore be made to promote venous flow, stabilize endothelium, and reduce blood viscosity. Pro-thrombotic factors precipitating stasis are preoperative (varicose veins; impaired cardiac output; dehydration), intraoperative (prolonged surgery; combined procedures; inappropriate positioning), and postoperative (immobility).[141-144] Obesity is a significant factor that influences outcome.[14,122,145] VTE risk is less than 1% in nonobese patients undergoing aesthetic surgery.[146,147] However, MWL patients are an entirely different physiological entity, with VTE rates of 10% after belt lipectomy.[55]

Risk stratification of VTE can be amalgamated into a single risk factor score using scoring systems such as the Caprini risk assessment model and updated Davison-Caprini risk assessment (Table 2).[148-150] After risk stratification, the combined Venturi, Caprini, Davison protocol recommends subcutaneous enoxaparin administered 12 hours postoperatively (30 mg if moderate risk, 40 mg if high risk) combined with intermittent pneumatic compression devices.[151] However, VTE still occurs in "low-risk" patients; therefore a lower threshold for prophylaxis is prudent.[145]

Unfortunately, no evidence-based validated tool is specific to abdominoplasty patients. Attempts have been made to evolve Caprini's scoring system to the plastic surgical setting, though difficultly exists in MWL patients especially due to the chronicity of disease, even after weight loss.[150-152] Despite the merits of risk stratification for VTE, patients should be considered on a case-by-case setting with a low threshold for prophylactic intervention in order to maximize patient safety. In the highest-risk patients, it is prudent to simply not operate.

Abdominoplasty activates the coagulation cascade, increasing thrombin levels and theoretically increasing VTE risk.[153-155] Mechanical prophylaxis with pre- and postoperative chemoprophylaxis (unfractionated heparin or low-molecular-weight heparin) significantly reduces thrombin levels to preoperative levels.[153] Conservative measures include hydration, warmth, minimizing pressure, perioperative mobilization, avoidance of long flights or further surgery, mechanical prophylaxis (TED stockings, intermittent pneumatic compression devices), and abstinence from smoking. Medical thromboprophylaxis and analgesia are necessary. Most patients require subcutaneous low-molecular-weight heparin (enoxaparin) or oral Factor Xa inhibitor apixaban (Eliquis, Bristol-Myers Squibb, NY and Pfizer, NY) and also wear TED stockings. Enoxaparin reduces DVT risk (20% to 0%; $P = 0.006$), but some data suggest it increases postoperative hematoma (0.5% to 7.3%; $P < 0.001$) and transfusion requirements (0.9% to 6.6%).[156] However, numerous studies demonstrate no increase in hematoma rates when enoxaparin is administered preoperatively[157] or postoperatively (at 1 hour,[158] 6 hours,[159] or for 2 days[157] after surgery).

Table 2. Modified Davison-Caprini Risk Assessment Model for Thromboembolic Disease

Risk factor category	Individual risk factor	Score
Predisposing risk factors	Age, 40–60 years	1
	Age, >60 years	2
	History of DVT	3
	Current pregnancy	1
	Current malignancy	2
	Obesity	1
	Oral contraceptive pills or HRT	1
	Hypercoagulable disorder	3
Exposing risk factors	Minor surgery	1
	Major surgery	2
	Immobilization	2
	Central venous access	2
	Previous MI/CHF	3
	Severe sepsis	3
	Free flap	3
	Hip, pelvis, leg fracture	5
	Stroke	5
	Multiple trauma	5
		Total

CHF, chronic heart failure; DVT, deep vein thrombosis; HRT, hormone replacement therapy; MI, myocardial infarction; Total, total risk assessment score from cumulative risk scores, where 1 = low risk; 2, moderate risk; 3, high risk; ≥4, highest risk.

Two-thirds of abdominoplasties are performed in combination with additional procedures.[160] Many studies report equivalence in complications during combined procedures.[122,161-163] However, extensive data suggest an increase in complications during combined procedures. Hester reported increased PE rates when surgical complexity increased from abdominoplasty alone (0% risk) to combinations with concurrent aesthetic surgery (0.9% risk) or abdominal surgery (1.7% risk).[122] Combining abdominoplasty with hysterectomy is also ill advised, because DVT risk increased from 0.2% to 1.4% and PE risk increases from 0.2% to 2.1%.[161] Further, a University of Texas Medical Center series demonstrated PE incidence increased from 4.7% for abdominoplasty alone to 5.5% with supplementary excisional procedures.[156] A recent publication by Winocour et al uses multiple surgeon, multiple institutional, national data from the CosmetAssure

database of 25,478 abdominoplasties.[49] Their data show a complication rate of 3.1% for abdominoplasty alone and an incremental increase in complication rates as more complex procedures are performed simultaneously with abdominoplasty (with liposuction, 3.8%; breast procedure, 4.3%; liposuction and breast procedure, 4.6%; body contouring procedure, 6.8%; liposuction and body contouring procedure, 10.4%). Circumferential abdominoplasty patients were most at risk of VTE.

If clinical symptoms (leg or chest pain, dyspnea, hemoptysis) or signs (warm, swollen or tender leg, tachypnea) of VTE are displayed, immediate general medical referral should be made and investigations performed (Duplex ultrasound, electrocardiogram, chest radiograph, lung function tests, computed tomography pulmonary angiogram) and heparin therapy instituted if indicated.

Infection

Necrotizing fasciitis is the most serious postoperative soft tissue infection and largely responsible for the 0.01% mortality rate after body contouring surgery. A high index of suspicion should be exercised in the unwell postoperative patient with a rapidly expanding rash, deranged blood markers, and metabolic acidosis. The laboratory risk indicator for necrotizing fasciitis is a useful adjunct for distinguishing necrotizing fasciitis from minor soft tissue infections.[164]

Less significant, but nevertheless important soft tissue infections can be minimized through rigorous aseptic practice. Furthermore, it is the senior author's practice to mandatorily follow an Methicillin-resistant *Staphylococcus aureus*-preventing protocol with preoperative chlorhexidine showers and application of intranasal and intra-umbilical mupirocin. Furthermore, the umbilicus is scrupulously cleaned before entering the operating room.

PATIENT-REPORTED OUTCOMES

Patients undergoing abdominoplasty have an improved quality of life with an increase in psychological parameters, including mental health, self-esteem, and intimacy and sexuality.[165] A total of 93% of patients support their decision to have undergone abdominoplasty with 98% satisfaction,[50,166] and sustained improvements in quality of life remain at 7 years postoperatively.[167,168] Patient-reported outcome measures (PROMs) are becoming specific to body contouring procedures, with the Post Bariatric Outcome Tool demonstrating positive application during validation testing.[169] The BODY-Q is being developed,[170] as is the Body-PROM and its 3 component modules relating to quality of life,[171] postoperative pain and disability scale, and patient and surgeon subjective/objective assessment scale.[172]

POSTOPERATIVE AESTHETIC CONCERNS

Abdominal Scar Too Long

Longer scars occur after fleur-de-lys abdominoplasty and HLTA. Experience dictates that if the scar is neat, optimally positioned, and facilitates a better result, a patient will accept a longer incision. However, it is imperative that if a longer scar technique is chosen, there is an appropriately matched tissue excess and vector of closure to warrant selecting a longer incision.

Scar Too High or Too Low

Greater skin excess and thicker tissue typically result in more unpredictable scaring, especially during HLTA procedures. Preoperative examination to pull excess tissue mitigates this risk, because markings are contemporaneously confirmed between surgeon and patient to visualize the intended result (Figure 5).

Pubis Too Wide

This is usually due to a failure to address the horizontal redundancy of the area at the first surgery. A wedge resection may reliably correct this.

Residual Skin at Upper Abdomen

This problem manifests particularly in MWL patients, because traditional abdominoplasty inadequately addresses the entire upper skin excess. Conversion to fleur-de-lys abdominoplasty or second-stage reverse abdominoplasty is indicated for definitive treatment, though additional procedures are not without further costs in terms of risk, time, and finances.

Residual Skin at Lower Abdomen

This problem presents as skin excess/fullness above the incision. If this persists after long-term healing, secondary liposuction or small resection is usually sufficient.

Residual Fat at the Abdomen

This aesthetic outcome is secondary to incomplete removal of subcutaneous fat, particularly within the undermined flap. Solutions include lipoabdominoplasty (immediate) or staged liposuction after the scars have settled (delayed).

Epigastric Recurrence/Residual Protrusion

Abdominal wall laxity, like any hernia, has a risk of recurrence. Contributory factors are patient related

(returning to exercise too soon or strenuously) or surgeon related (incomplete or inadequate rectus fascial repair, especially inadequate plication to the xiphoid resulting in a superior bulge). Significant hernia warrants formal repair.

Dog-Ears

Dog-ears at the lateral wound edges are almost inevitable given the global tissue redundancy and complex vectors on closure. Well-planned markings, oblique skin alignment, beginning closure laterally, extending incisions, and lateral liposuction minimize the risk. If dog-ears do occur, excision can be performed under local anesthesia in the office setting at a later date.

CONCLUSIONS

Abdominal contouring procedures offer patients the opportunity to truly improve their body image and quality of life. Despite the many choices available to the surgeon, by balancing the aesthetic demands of each individual patient with their unique surgical risk, one can select a body contouring procedure that is at once the most effective and the safest.

Supplementary Material

This article contains supplementary material located online at www.aestheticsurgeryjournal.com.

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