

# Cosmetic Liposuction: Preoperative Risk Factors, Major Complication Rates, and Safety of Combined Procedures

Aesthetic Surgery Journal  
2017, Vol 37(6) 680–694  
© 2017 The American Society for  
Aesthetic Plastic Surgery, Inc.  
Reprints and permission:  
journals.permissions@oup.com  
DOI: 10.1093/asj/sjw243  
www.aestheticsurgeryjournal.com  
**OXFORD**  
UNIVERSITY PRESS

Christodoulos Kaoutzanis, MD; Varun Gupta, MD, MPH;  
Julian Winocour, MD; John Layliev, MD; Roberto Ramirez, MD;  
James C. Grotting, MD, FACS; and Kent Higdon, MD, FACS

## Abstract

**Background:** Liposuction is among the most commonly performed aesthetic procedures, and is being performed increasingly as an adjunct to other procedures.

**Objectives:** To report the incidence and risk factors of significant complications after liposuction, and to determine whether adding liposuction to other cosmetic surgical procedures impacts the complication risk.

**Methods:** A prospective cohort of patients who underwent liposuction between 2008 and 2013 was identified from the CosmetAssure database. Primary outcome was occurrence of major complications requiring emergency room visit, hospital admission, or reoperation within 30 days of the operation. Univariate and multivariate analysis evaluated risk factors including age, gender, body mass index (BMI), smoking, diabetes, type of surgical facility, and combined procedures.

**Results:** Of the 31,010 liposuction procedures, only 11,490 (37.1%) were performed as a solitary procedure. Liposuction alone had a major complication rate of 0.7% with hematoma (0.15%), pulmonary complications (0.1%), infection (0.1%), and confirmed venous thromboembolism (VTE) (0.06%) being the most common. Independent predictors of major complications included combined procedures (Relative Risk (RR) 4.81), age (RR 1.01), BMI (RR 1.05), and procedures performed in hospitals (RR 1.36). When examining specifically other aesthetic procedures performed alone or with liposuction, combined procedures had a higher risk of confirmed VTE (RR 5.65), pulmonary complications (RR 2.72), and infection (RR 2.41), but paradoxically lower hematoma risk (RR 0.77) than solitary procedures.

**Conclusions:** Liposuction performed alone is a safe procedure with a low risk of major complications. Combined procedures, especially on obese or older individuals, can significantly increase complication rates. The impact of liposuction on the risk of hematoma in combined procedures needs further investigation.

## Level of Evidence: 2

Editorial Decision date: November 15, 2016; online publish-ahead-of-print April 20, 2017.



Drs Kaoutzanis, Winocour, Layliev, and Ramirez are Plastic Surgery Fellows, and Drs Gupta and Higdon are Assistant Professors, Department of Plastic Surgery, Vanderbilt University, Nashville, TN. Dr Grotting is a Clinical Professor, Division of Plastic Surgery, University of Alabama, Birmingham, AL; and CME/MOC Section Editor for *Aesthetic Surgery Journal*.

## Corresponding Author:

Dr Christodoulos Kaoutzanis, Department of Plastic Surgery, Vanderbilt University, D-4207 Medical Center North, Nashville, TN 37232-2345, USA.  
E-mail: [ckaoutzanis@gmail.com](mailto:ckaoutzanis@gmail.com)

Presented at: The 94th Annual Meeting of the American Association of Plastic Surgeons in Scottsdale, AZ in April 2015.

Over the last few decades, aesthetic plastic surgery has seen a considerable growth in the United States. According to the American Society for Aesthetic Plastic Surgery (ASAPS), 1.9 million cosmetic surgical procedures were performed in 2015, an increase of 94% since 1997.<sup>1</sup> Suction-assisted lipectomy, or liposuction, was the most popular of these cosmetic surgical procedures for both men and women in 2015, with 396,048 procedures performed.<sup>1</sup> This represents a 124% increase in the number of liposuction procedures since 1997, with an increase of 16% last year alone.<sup>1</sup> The increased popularity of liposuction extends beyond North America, and according to the International Society of Aesthetic Plastic Surgery (ISAPS), liposuction ranks second behind breast augmentation surgeries in worldwide procedures (1,394,588 procedures performed in 2015).<sup>2</sup>

The dramatic adoption of liposuction as a solitary procedure and adjunct to other cosmetic procedures has stimulated its technical evolution from simple aspiration of fat to more sophisticated body sculpting, including fat grafting.<sup>3</sup> Nevertheless, despite the widespread acceptance and popularity of the procedure, which now spans multiple medical specialties, there is relatively little scientific evidence on its safety from large multi-institutional groups. Currently, available literature focuses primarily on liposuction techniques and complications from small case series or surveys. Without larger sample sizes and multi-institutional or multi-surgeon studies, with standardized practitioner training, it is difficult to generalize conclusions. This is necessary to educate patients preoperatively and help them make informed decisions. In addition, to the best of our knowledge, minimal data exists on risk factors for the development of major complications following liposuction that can ultimately optimize patient outcomes and reduce healthcare expenditure.

This study queried the large, prospective, multicenter CosmetAssure (Aesthetic Surgeons' Financial Group, Birmingham, AL) insurance database to determine the incidence of major postoperative complications in patients undergoing liposuction. Additional goals were to define procedures commonly combined with liposuction, to compare complication rates of liposuction done alone with liposuction done in combination with other cosmetic surgical procedures, and to evaluate significant risk factors associated with major complications following liposuction. Finally, since liposuction is increasingly performed as an adjunct to other procedures, we examined whether there was a significant difference in complication rates when individual cosmetic surgical procedures were performed alone or combined with liposuction.

## METHODS

### Study Population

This prospective cohort study was approved by the Institutional Review Board at Vanderbilt University

(Reference number 140082). The study population comprised of a cohort of patients who enrolled into the CosmetAssure insurance program and underwent cosmetic surgical procedure(s) between May 2008 and May 2013. The CosmetAssure database was accessed in February 2014 following approval by the Institutional Review Board.

## Database

As previously described by our group,<sup>4</sup> CosmetAssure is an insurance program that covers the cost of unexpected major complications from 24 covered cosmetic surgical procedures, which may not be reimbursed by the patient's primary insurer. CosmetAssure was introduced in 2003 and has been prospectively collecting data on patient risk factors for research purposes since 2008. This insurance program covers all 50 states in the United States. It is available to American Board of Plastic Surgery (ABPS) – certified plastic surgeons and is endorsed by the American Society of Plastic Surgeons (ASPS). The program is also available to ASPS Candidates for Membership who have passed the ABPS Written Examination. Every patient undergoing any covered procedure at participating practices is required to enroll in the program. Patients' demographics and risk factor information are entered into the database prior to undergoing the procedure, thus making it a prospective cohort. Surgeon-reported major complications, filed as a claim, are recorded in the database. Personnel employed by CosmetAssure enter data provided by the surgeon at the time of patient enrollment, as well as any claims filed by the surgeon. CosmetAssure, being a private insurance company, has a vested interest in maintaining an accurate database for actuarial and audit purposes. Major complication is defined as that occurring within 30 days of the operation that requires emergency room visit, hospital admission, or reoperation. This excludes complications that can be managed in the clinic, such as minor wound infections and small seromas, as they are not eligible for insurance claim. The covered major complications include hematoma, surgical site infection, wound-related problem, pulmonary dysfunction, suspected or confirmed venous thromboembolism (VTE), cardiac complication, myocardial infarction, and fluid overload. Suspected VTE represents patients that required work-up for clinical symptoms of a thrombotic event, however, was proven to be negative and, therefore, required no further management. Confirmed VTE represents patients that have undergone imaging work-up, and the diagnosis was confirmed. Other major complications (eg, nerve injury, urinary retention, etc.) have been reported to CosmetAssure but may not qualify for compensation. The database lists all procedures performed on the patient, making it possible to study specific individual procedures as well as procedure combinations

(ie, patients undergoing multiple procedures under the same anesthetic). The database also records demographic and comorbidity data including age, gender, body mass index (BMI), smoking, self-reported diabetes mellitus (including both type 1 and type 2), and type of surgical facility (office-based surgical suites, accredited surgical centers, and hospitals).

## Exposure

In this study cohort, exposure was defined as the type of cosmetic surgical procedure(s) performed. Liposuction was studied as the primary exposure, whether it was performed alone or in combination with abdominoplasty, breast procedures (augmentation, reduction, revisional breast implant procedures, mastopexy, male breast surgery), non-abdominoplasty body procedures (brachioplasty, buttock lift, calf implant, labioplasty, lower body lift, thigh lift, upper body lift), and/or face procedures (blepharoplasty, browlift, cheek implant, chin augmentation, facelift, otoplasty, rhinoplasty).

## Outcome

Primary outcome was the occurrence of any major complication(s) (as defined above) requiring emergency room visit, hospital admission, or reoperation within 30 days of the index operation. Secondary outcome studied was the type of complication.

## Risk Factors

The potential risk factors evaluated included age, gender, BMI, smoking, diabetes mellitus, type of surgical facility, and combined procedures.

## Statistical Analysis

As previously described by our group,<sup>4</sup> two separate, de-identified datasets were obtained from CosmetAssure, one with the enrollment data and the other with claims information. The enrollment dataset contained entries for each unique procedure. Thus, a patient undergoing combined procedures had separate entries for each procedure. A unique identifier was created using variables: date of birth, date of surgery, and BMI. Using this unique identifier, the enrollment dataset was restructured such that a patient undergoing combined procedures was counted once, with each of the procedures listed as a separate variable. Another unique identifier was created with variables shared between the enrollment and claims datasets; date of birth, date of surgery, and gender. This identifier was then used to match the claims dataset to the restructured enrollment dataset. Of

the 2506 patients in the claims dataset, 20 did not match the enrollment data using the identifier. These cases were manually matched to enrollees with the closest demographic characteristics. The Kolmogorov-Smirnov statistic was used to check normal distribution of continuous variables (age and BMI). The only missing data were absent BMI information for 1046 (0.8%) patients. Similarly, in the liposuction subset, 260 of the 31,010 patients (0.8%) did not have the BMI information. These patients were included in the analysis without replacing these missing data points. Patients with missing BMI information were automatically excluded in regression analysis. Patient characteristics, risk factors, and complication rates between patients undergoing different procedure combinations were compared by two-tailed *t* test, Fisher exact test, or Pearson chi-square test. For the purpose of univariate analysis, age and BMI were recorded as ordinal variables with clinically appropriate categories. Standard logistic regression analysis was performed to identify the independent risk factors for postoperative complications. For the purpose of logistic regression analysis, age and BMI were used as continuous variables. Outcomes were reported as 30-day incidence rates after the surgery. Unless otherwise noted, probability of type I error of less than 5% ( $P < 0.05$ ) was used to determine statistical significance. All analyses were performed using IBM SPSS Statistics 23.0 software (IBM Corporation, Armonk, NY).

To study the effect on complication risk from addition of liposuction to other cosmetic surgical procedures, a subset analysis was performed on a sample comprising of patients undergoing other individual cosmetic procedures performed alone or only in combination with liposuction. This allowed us to eliminate the confounding effect of multiple different procedure combinations and enabled us to specifically look at the impact of liposuction. Univariate and multivariate analysis, as outlined above, compared complication rates of combined procedures (with liposuction) and solitary procedures (without liposuction).

## RESULTS

Between May of 2008 and May of 2013, a total of 183,914 cosmetic surgery procedures were performed on 129,007 patients who enrolled in the CosmetAssure insurance program. Overall, the mean age of the entire cohort was  $40.9 \pm 13.9$  years (range, 5-93 years) and the mean BMI was  $24.3 \pm 4.4$  kg/m<sup>2</sup> (range, 17.0-56.3 kg/m<sup>2</sup>). There were 8357 men (6.5%) and 120,650 women (93.5%) in the dataset. Active smoking was reported by 10,621 (8.2%) patients. Self-reported diabetes was recorded in 2368 (1.8%) of patients. Major complications occurred in 2506 patients (1.9% complication rate).

Demographics and Complications of Liposuction Group

A total of 31,010 liposuction procedures were performed, representing 16.9% of all 183,914 cosmetic procedures. Of these, 11,490 (37.1%) were performed as a solitary procedure and 19,520 (62.9%) with additional procedures (Figure 1). Overall, mean age was 42.1 ± 12.0 years (range, 15-82 years), and mean BMI was 26.4 ± 4.6 kg/m<sup>2</sup> (range, 18.6-55.8 kg/m<sup>2</sup>). In the liposuction cohort, there were more males (9.1% vs 5.7%, *P* < 0.01), fewer smokers (6.0% vs 8.9%, *P* < 0.01), and more patients had pre-existing diabetes mellitus (2.0% vs 1.8%, *P* < 0.01). Similar to other procedures, liposuction procedures were most commonly performed in accredited surgical centers (54.8%), followed by hospitals (27.5%) and office-based surgical suites (17.7 %). Patient demographics and other characteristics comparing the two patient populations (ie, liposuction vs all other cosmetic procedures) are shown in Table 1.

Liposuction Patient Profile Over 5 Years

Between 2008 and 2013, the proportion of patients undergoing liposuction over the age of 45 had increased from 35.7% to 38.7% (*P* < 0.01). The proportion of overweight patients also increased from 56.4% to 58.4% (*P* < 0.01). Prevalence of smoking decreased from 6.8% to 5.2%. Interestingly, liposuction performed as a solitary procedure decreased from 37.1% to 33.8% (*P* < 0.01). There was no statistically significant change in other demographic characteristics or complication rates among liposuction patients during this time interval.

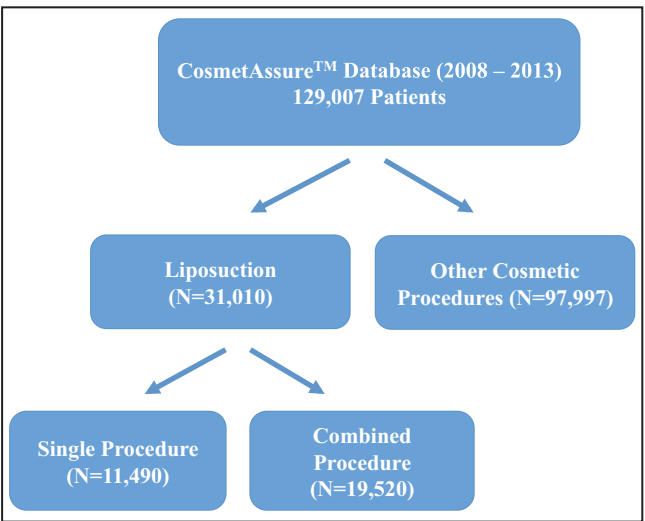


Figure 1. Study design.

Complications of Liposuction

Major complications occurred in 759 patients in the liposuction group (2.4% complication rate). Liposuction performed as a solitary procedure had a low overall complication rate of 0.7 % (N = 81), but when procedures were combined with liposuction an overall complication rate of 3.5% was observed (N = 678). The most common complications following solitary liposuction were hematoma (N = 17, 0.15%), pulmonary dysfunction (N = 12, 0.1%), surgical site infection (N = 11, 0.1%), and confirmed VTE (N = 7, 0.06%). Of note, the incidence of suspected VTE was 0.19% (N = 22).

Combined Procedures

Liposuction was performed as a combined procedure in 19,520 (62.9%) cases. When compared to patients getting liposuction alone, those who underwent combined procedures had fewer males (5.5% vs 15.2%, *P* < 0.01). Combined procedures were more likely to be performed in hospital settings (30.3% vs 22.6%), and were less likely to be performed in office-based surgical suites (14.1% vs 24.0%). Most common complications among combined procedures were surgical site infection (0.7%), hematoma (0.6%), possible or confirmed VTE (0.6%), and pulmonary dysfunction (0.2%).

Three hundred and twelve procedure combinations were identified in the liposuction cohort. Thus, for the purpose of this study, we categorized combined procedures into 4 groups based on body region: abdominoplasty, non-abdominoplasty body procedures, breast procedures, and face procedures. Among combined procedures, liposuction with abdominoplasty, liposuction with breast procedures, and liposuction with abdominoplasty and breast procedures were the most frequent combination procedures at 22.4% (N = 6946), 14.9% (N = 4606) and 10.8% (N = 3364) of all liposuctions, respectively. The frequency and complication rates of different procedure combinations are shown in Table 2.

Risk Factors for Any Major Complication

Univariate analysis showed female gender, higher BMI, surgery performed in a hospital or accredited surgical center, and combined procedures to be associated with statistically significant increased complication rates. Female patients had a complication rate of 2.5% compared to 1.7% in males (*P* < 0.01). Morbidly obese patients had a complication rate of 6.3% when compared to 1.8% in normal weight patients (*P* < 0.01) (Figure 2A). The incidence of major complications for procedures performed in office-based surgical suites was 1.6%, followed by 2.3% in accredited surgical centers, and 3.3% in hospitals (*P* < 0.01) (Figure



**Table 1.** Clinical and Demographic Characteristics

Variable	Liposuction (N = 31,010)	All other cosmetic procedures (N = 97,997)	P value
Age (years), mean $\pm$ SD	42.1 $\pm$ 12.0	40.4 $\pm$ 14.5	<0.01
Male gender, N (%)	2817 (9.1%)	5540 (5.7%)	<0.01
Body mass index (kg/m <sup>2</sup> ), mean $\pm$ SD	26.4 $\pm$ 4.6	23.7 $\pm$ 4.4	<0.01
Body mass index $\geq$ 25 kg/m <sup>2</sup> , N (%)	17,491 (56.9%)	28,834 (29.7%)	<0.01
Smoking, N (%)	1866 (6.0%)	8755 (8.9%)	<0.01
Diabetes mellitus, N (%)	632 (2.0%)	1736 (1.8%)	<0.01
Type of facility, N (%)			<0.01
Accredited surgical center	16,992 (54.8%)	57,002 (58.2%)	
Hospital	8516 (27.5%)	25,961 (26.5%)	
Office-based surgical suite	5502 (17.7%)	15,034 (15.3%)	
Combined procedures, N (%)	19,520 (62.9%)	-	<0.01
Complications, N (%)	759 (2.4%)	1747 (1.8%)	<0.01

(%): frequencies, SD: standard deviation.

**Table 2.** Complication Rates in Different Procedure Combinations

Body region(s)	Frequency	Percent	Complication rate (%)
Liposuction alone	11,501	37.1	0.7
Liposuction with:			
Abdominoplasty	6946	22.4	3.8
Abdominoplasty + Breast	3364	10.8	4.6
Abdominoplasty + Body	386	1.2	10.4
Abdominoplasty + Face	249	0.8	4.0
Breast	4606	14.9	1.8
Body	1450	4.7	5.0
Face	1748	5.6	1.1
Breast + Body	230	0.7	5.2
Breast + Face	255	0.8	2.0
Body + Face	52	0.2	1.9
Breast + Body + Face	11	0	0

Breast: augmentation, reduction, revision breast implant procedures, mastopexy, male breast surgery. Body: brachioplasty, buttock lift, calf implant, labioplasty, lower body lift, thigh lift, upper body lift. Face: blepharoplasty, brow lift, cheek implant, chin augmentation, facelift, facial resurfacing, hair replacement, otoplasty, rhinoplasty.

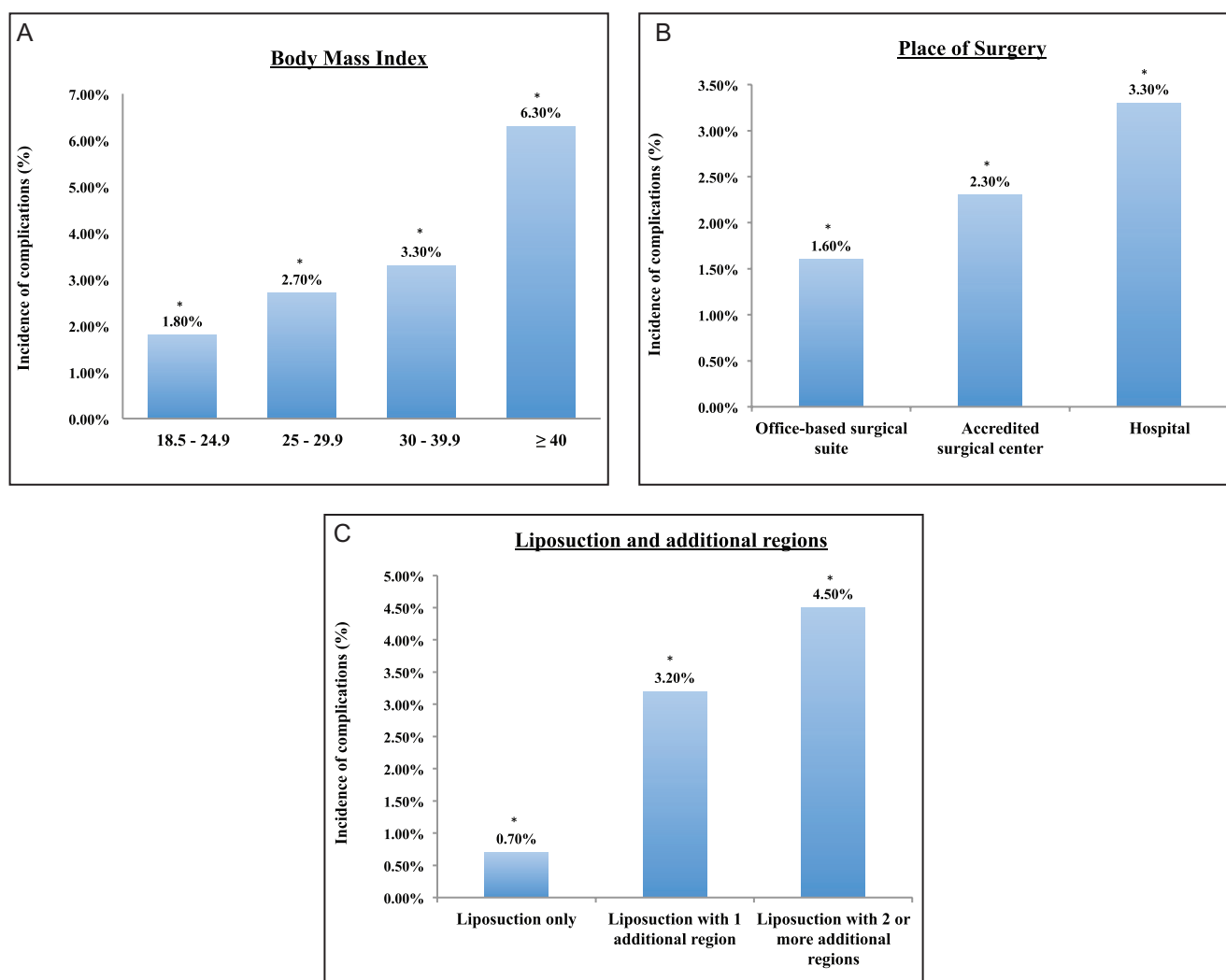
2B). As previously stated, liposuction alone carried a complication rate of 0.7% compared to 3.5% in combined procedures ( $P < 0.01$ ). Patients over the age of 45 developed complications in 2.6% of cases, compared to 2.3% in younger patients ( $P = 0.14$ ). Smokers and diabetics had

slightly higher complication rates, but the difference was not statistically significant (2.6% vs 2.4%,  $P = 0.71$ , and 3.2% vs 2.4%,  $P = 0.24$ , respectively).

On multivariate regression analysis, combined procedures had a significantly higher risk of complications compared to liposuction alone as dictated by the risk inherent to the procedure(s) being combined with liposuction. After eliminating the effect of combined procedures, age (Relative Risk [RR] 1.01, 95% Confidence Interval [CI] 1.002–1.015), BMI (RR 1.05, 95% CI 1.04–1.07), and procedures performed in hospitals (RR 1.36, 95% CI 1.17–1.58) were independent predictors for any major complication (Table 3). BMI was an independent risk factor for surgical site infections (RR 1.09, 95% CI 1.06–1.11,  $P < 0.01$ ) (Table 4), pulmonary complications (RR 1.06, 95% CI 1.01–1.10,  $P = 0.01$ ) and confirmed VTE (RR 1.07, 95% CI 1.02–1.11,  $P < 0.01$ ). Risk of pulmonary complications (RR 1.03, 95% CI 1.007–1.048,  $P < 0.01$ ) and confirmed VTE (RR 1.03, 95% CI 1.006–1.047,  $P = 0.01$ ) also increased slightly with age. Females had a significantly lower risk of hematomas (RR .61, 95% CI 0.38–0.96) (Table 5).

## Single Cosmetic Procedures Combined with Liposuction: Impact on Complication Rates

The risk factor profile and complications in patients undergoing single cosmetic procedures in combination with liposuction ( $n = 12,961$ ) was compared to those undergoing single cosmetic procedures alone ( $n = 75,530$ ) (Table 6). On univariate analysis, single cosmetic procedures in



**Figure 2.** (A) Univariate analysis of BMI as a risk factor for liposuction (\* $P < 0.05$ ). (B) Univariate analysis of place of surgery as a risk factor for liposuction (\* $P < 0.05$ ). (C) Univariate analysis of liposuction and additional regions as a risk factor for Liposuction (\* $P < 0.05$ ).

combination with liposuction had a higher incidence of any major complication (3.1% vs 1.5%,  $P < 0.01$ ), infection (1.0% vs 0.3%,  $P < 0.01$ ), confirmed VTE (0.3% vs 0%,  $P < 0.01$ ), suspected VTE (0.5% vs 0.1%,  $P < 0.01$ ), and pulmonary complications (0.3% vs 0.1%,  $P < 0.01$ ) compared to cosmetic procedures performed alone. On the contrary, when single cosmetic procedures were combined with liposuction the hematoma rate was significantly lower when compared to cosmetic procedures performed alone (0.7 vs 0.9%,  $P = 0.04$ ).

Multivariate analysis confirmed that single cosmetic procedures in combination with liposuction had a statistically significant higher incidence of any major complication when compared to those cosmetic procedures performed alone (RR 1.77, 95% CI 1.57-1.99,  $P < 0.01$ ) (Table 7). Further analysis of individual complications demonstrated confirmed VTE (RR 5.65, 95% CI 3.40-9.41,  $P < 0.01$ ),

pulmonary complication (RR 2.72, 95% CI 1.80-4.11,  $P < 0.01$ ), and surgical site infection (RR 2.41, 95% CI 1.94-3.00,  $P < 0.01$ ) to be more likely after combined procedures compared to isolated cosmetic procedures. However, risk of hematoma was found to be significantly lower in combined procedures when compared to isolated cosmetic procedures (RR 0.77, 95% CI 0.62-0.96,  $P = 0.02$ ).

## DISCUSSION

Liposuction is an excellent procedure for the purpose of body sculpting that involves removal of localized or regional deposits of adipose tissue, however, it is not a treatment for general obesity. Since its introduction in the United States in 1982, liposuction has become the most commonly performed cosmetic surgical procedure in plastic surgery.<sup>1</sup> Advances in liposuction techniques

**Table 3.** Risk Factors for Major Complications Following Liposuction

Risk factor	Relative risk	95% Confidence interval	P value
Age	1.01	1.002-1.015	<0.01*
Female gender	1.15	0.85-1.56	0.36
Body mass index	1.05	1.04-1.07	<0.01*
Smoking	1.07	0.79-1.44	0.66
Diabetes mellitus	1.03	0.65-1.63	0.90
Hospital procedures <sup>§</sup>	1.36	1.17-1.58	<0.01*
Combined procedures	4.81	3.80-6.07	<0.01*

§ Compared to accredited surgical center and office-based procedures. \* Significant  $P < 0.05$ .

over the years have decreased the risks involved and improved the safety of the procedure. Nevertheless, like any other procedure, major complications can occur following liposuction that may lead to a potentially devastating cosmetic outcome and pose significant financial burden on the patient and the surgeon. Identifying factors that increase the risk of complications following liposuction has the potential to minimize these problems with their undesirable consequences and optimize aesthetic outcomes. It is for these reasons that there is a need for reliable studies examining surgical outcomes and risk factors related to these outcomes that are generalizable to various practice models. Current literature on liposuction complications is limited by small sample size, single institution or single surgeon experience, and variation in training and qualifications of the physicians performing the procedure. Most of the studies with high power are survey-based, hence subject to the many statistical weaknesses inherent in those study types.<sup>5</sup> The CosmetAssure database provides a sufficient number of cases not only to allow analysis of the major complications following liposuction, but also to evaluate risk factors associated with them. This has a considerable advantage over single center studies, and even review articles on this topic, which would require a prohibitively large number of participants to detect these differences.

**Liposuction Complications**

In the existing literature, the incidence of complications following liposuction ranges from 0% to 10%, with inconsistencies of reported data between different specialties, such as plastic surgery and dermatology, making an accurate assessment of the risk profile of cosmetic liposuction challenging.<sup>5-11</sup> Our multi-institutional prospective cohort

**Table 4.** Risk Factors for Major Surgical Site Infections Following Liposuction

Risk factor	Relative risk	95% Confidence interval	P value
Age	1.00	0.99-1.02	0.55
Female gender	1.68	0.86-3.30	0.13
Body mass index	1.09	1.06-1.11	<0.01*
Smoking	1.46	0.90-2.38	0.13
Diabetes mellitus	1.58	0.79-3.11	0.20
Hospital procedures <sup>§</sup>	1.09	0.81-1.45	0.58
Combined procedures	10.06	5.47-18.52	<0.01*

§ Compared to accredited surgical center and office-based procedures. \* Significant  $P < 0.05$ .

of 31,010 patients who underwent liposuction alone or in combination with other cosmetic surgical procedures throughout the United States represents the largest study in the current literature to date and revealed a relatively low overall incidence of major postoperative complications. We identified 759 major complications with an overall complication rate of 2.4%. There are several possible explanations for the low incidence of complications that was noted in our analysis. Most importantly, this study captured only major complications requiring emergency room visit, hospital admission, or reoperation, rather than those dealt with in the office setting. In addition, the standardization of the plastic surgery practitioners in the CosmetAssure database might have also contributed to this finding, with proper patient selection and safe practice measures implemented by board certified plastic surgeons.

During the early days of liposuction with the use of the dry technique and larger instruments, significant intraoperative bleeding occurred and a considerable amount of postoperative hematomas were observed.<sup>12</sup> Fortunately, with the introduction of tumescent and wet techniques, as well as the use of less traumatic smaller cannulas, the blood loss and hematomas were significantly reduced in all series.<sup>13-16</sup> Lehnhardt et al analyzed 72 liposuction related deaths in Germany between 1998 and 2002, and stated that all deaths related to massive blood loss (7 cases) occurred in cases of high volume liposuction (2.4-24 liters) with a prolonged operative time.<sup>10</sup> In our study, one death from a combined breast augmentation/liposuction procedure was found within the database. However, CosmetAssure does not mandate reporting of deaths, and unless it is preceded by one of the covered major complications, it is unlikely to be reported.<sup>17</sup> Hematomas were found to be the most common major complication of liposuction with an incidence of 0.15% (N = 17). Although several measures have been previously proposed to reduce

the risk of bleeding, such as holding preoperatively medications that are shown to increase postoperative bleeding and use of compression garments, there is very little

**Table 5.** Risk Factors for Major Hematomas Following Liposuction

Risk factor	Relative risk	95% Confidence interval	P value
Age	1.00	0.99-1.02	0.60
Female gender	0.61	0.38-0.96	0.04*
Body mass index	1.03	0.99-1.02	0.09
Smoking	1.12	0.94-1.51	0.69
Diabetes mellitus	1.27	0.75-1.94	0.57
Hospital procedures §	1.29	1.28-2.04	0.09
Combined procedures	6.81	0.62-0.96	<0.01*

§ Compared to accredited surgical center and office-based procedures. \* Significant  $P < 0.05$ .

scientific evidence as to which risk factors are involved in the development of hematomas.<sup>14</sup> Mangubat and Harbke indicated that patient weight, surgery time, and supernatant volume play a significant role in predicting blood loss following liposuction.<sup>18</sup>

Our analysis revealed pulmonary complications to be the second most common adverse outcome following liposuction, with an incidence of 0.1% ( $N = 12$ ). In our data set, pulmonary complications do not include VTE or pneumonia, which were identified by CosmetAssure as claims separate and different from this outcome. Although we were unable to determine the exact nature of the pulmonary complications in our series, we can speculate that these may include dyspnea, pulmonary edema, or lung collections. With the advent of large volume liposuction, careful fluid management has become essential to avoid significant fluid changes that may affect the hemodynamic status of the patient. Pulmonary edema following large volume liposuction is rare but has been reported by

**Table 6.** Frequency of Commonly Performed Cosmetic Procedures Alone and With Liposuction

Procedure	Frequency of single cosmetic procedures (%) ( $N = 75,530$ )	Complication rate (%)	Frequency of single cosmetic procedures combined with liposuction (%) ( $N = 12,961$ )	Complication rate (%)	P value
<b>Breast</b>					
Breast augmentation	41,836 (55.39%)	1.4	1824 (14.07%)	1.7	0.26
Breast mastopexy	3397 (4.50%)	1.1	780 (6.02%)	1.9	0.11
Breast reduction	3094 (4.10%)	1.5	513 (3.96%)	2.3	0.18
Male breast surgery	1530 (2.03%)	1.8	374 (2.89%)	1.9	0.83
<b>Body</b>					
Abdominoplasty	8975 (11.88%)	3.1	6946 (53.59%)	3.8	0.01
Brachioplasty	762 (1.01%)	1.3	223 (1.72%)	3.6	0.04
Buttock lift	407 (0.54%)	3.4	751 (5.79%)	3.6	1.0
Labioplasty	64 (0.08%)	0	1 (0.01%)	0	-
Lower body lift	426 (0.56%)	7.0	167 (1.29%)	9.0	0.49
Thigh lift	405 (0.54%)	4.7	200 (1.54%)	6.5	0.34
Upper body lift	26 (0.03%)	0	2 (0.02%)	0	-
<b>Face</b>					
Blepharoplasty	4879 (6.46%)	0.4	401 (3.09%)	1.5	0.01
Brow lift	441 (0.58%)	0.7	52 (0.40%)	0	1.0
Cheek implant	33 (0.04%)	3.0	10 (0.08%)	0	1.0
Chin augmentation	157 (0.21%)	1.9	80 (0.62%)	0	0.55
Facelift	4809 (6.37%)	1.5	455 (3.51%)	1.1	0.68
Otoplasty	679 (0.90%)	0.7	5 (0.04%)	0	1.0
Rhinoplasty	3608 (4.78%)	0.6	177 (1.37%)	0.6	1.0



**Table 7.** Risk Factors for Major Complications When Single Cosmetic Procedures Were Combined With Liposuction

Risk factor	Relative risk	95% Confidence interval	P value
Age	1.008	1.005-1.012	<0.01*
Male gender	0.96	0.79-1.17	0.70
Body mass index	1.05	1.04-1.06	<0.01*
Smoking	1.23	1.04-1.46	0.02*
Diabetes mellitus	1.36	1.01-1.82	0.04*
Hospital procedures <sup>§</sup>	1.59	1.35-1.88	<0.01*
Combined procedures	1.77	1.57-1.99	<0.01*

§ Compared to accredited surgical center and office-based procedures. \* Significant  $P < 0.05$ .

several authors.<sup>19,20</sup> Lung collections following abdominal organ perforations are even rarer, but have been previously described.<sup>21</sup>

Surgical site infection was the third most common complication seen in our study, occurring in 0.1% ( $N = 11$ ) of all liposuction procedures. This is consistent with the literature with reported rates of less than 1%.<sup>6,14,22,23</sup> It has been postulated that one of the most common causes for these infections is the presence of a hematoma in the subcutaneous tissues resulting in secondary bacterial contamination.<sup>22</sup> The most frequently isolated bacteria include *Staphylococcus aureus*, group A *Streptococcus*, *Streptococcus pyogenes*, as well as synergistic infections with anaerobic and facultative anaerobic bacteria.<sup>24-26</sup> However, sporadic cases of infections due to *Mycobacteria* outbreaks have also been described.<sup>27-31</sup> Diagnosis of these infections in a timely manner is difficult due to their indolent course and the low index of suspicion from the clinicians. Localized wound infections can progress, sometimes rapidly, to necrotizing fasciitis with serious or even fatal outcomes.<sup>25,26,32-36</sup> There is scant literature with regards to risk factors for the occurrence of infection following liposuction. Prior authors have investigated the influence of the amount of fat aspirated and associated procedures performed with liposuction on the occurrence of infections but no significant differences were noted between the groups.<sup>6</sup> Other authors reported several risk factors for development of necrotizing fasciitis after liposuction including age greater than 50 years, alcohol abuse, intravenous drug abuse, diabetes mellitus, peripheral vascular disease, gastrointestinal malignancy, immunosuppressed state, and malnutrition.<sup>35</sup> In our analysis, we found only high BMI to be a significant risk factor for developing major infection. This is in agreement with one of our prior studies on 129,007 patients from CosmetAssure database, where obesity was found to be an independent

risk factor for surgical site infections following cosmetic surgical procedures.<sup>37</sup>

VTE, although rare, remains one of the most feared complications after aesthetic surgery. There is paucity of published literature with very few large-scale studies evaluating the incidence of this outcome in patients undergoing liposuction. In a systemic review, Miskiewicz et al reported low rates of deep vein thrombosis following liposuction ranging from 0% to 0.59%.<sup>38</sup> Newall et al reported no deep vein thrombosis in a retrospective series of patients who underwent large-volume liposuction and received chemoprophylaxis with low molecular weight heparin.<sup>39</sup> Our findings are consistent with the available literature. When all liposuction procedures were examined, we found an incidence of 0.4% and 0.2% for possible and confirmed VTE, respectively. In contrast, following isolated liposuction the incidences of suspected and confirmed VTE were even lower at 0.19% ( $N = 22$ ) and 0.06% ( $N = 7$ ), respectively. Despite that, confirmed VTE was the fourth most commonly reported complication after isolated liposuction. As far as factors that may contribute to the risk of VTE, no information is available in the database for American Society of Anesthesiologists (ASA) classification, anesthesia type, chemoprophylaxis and mechanical prophylaxis, intraoperative temperature and blood pressure management, intraoperative blood loss, or duration of surgery. In addition, there is no information about hormone therapy use, over the counter contraceptives, or other medications that could influence a patient's VTE risk. Equally no information is known on history of blood disorders, blood dyscrasias or venous insufficiency that could contribute to a prothrombotic state.

The importance of the effect of liposuction on the coagulation cascade has been previously investigated using a computerized thromboelastograph coagulation analyzer.<sup>40</sup> The authors showed that patients undergoing suction-assisted liposuction had decreased initial clotting time, decreased time to full clot formation, increased pro-coagulability state and increased clot rigidity. Despite that, appropriate risk assignment and prophylaxis for the prevention of VTE in patients undergoing liposuction remain a challenge, and like other areas in aesthetic surgery are not clearly defined. It has been suggested that physicians should adopt a risk gradation system for their practices based on the available data from the American College of Chest Physicians Guidelines and other risk-assessment models such as the 2005 Caprini risk-assessment model, which has been shown to be a better predictor of the VTE risk than the 2010 modifications in adult plastic surgery patients.<sup>3,41,42</sup> However, many plastic surgeons do not follow or even know the ASPS guidelines for preoperative VTE prevention and treatment.<sup>43</sup>

## Risk Factors

Even though major complications following liposuction are rare, they can have devastating cosmetic outcomes and potentially life-threatening effects. Therefore, identifying factors that increase the risk of these complications has the potential to minimize the untoward consequences and optimize aesthetic outcomes. The CosmetAssure database provides a large number of liposuction cases, allowing thus evaluation of specific risk factors associated with these complications. This offers a significant benefit when compared to single center studies or even review articles on this topic, which would require a prohibitively large number of participants to detect these differences. To the best of our knowledge, our study represents the largest in current literature examining several factors, both patient and procedure related, that impact major complications.

As overall human life expectancy continues to rise, the number of elderly patients continues to increase, which has led to more elderly patients seeking plastic surgery. In our study, the proportion of patients undergoing liposuction over the age of 45 has increased from 35.7% to 38.7% over the 5-year period of this study. Physiologic age-related changes and underlying disease states have been thought to confound evaluation of age as a risk factor for any type of surgical procedure.<sup>44</sup> Previous literature on patient age as an independent risk factor for complications following liposuction is lacking. Our study has shown that advanced age is associated with a slight increase in the risk of major complications following liposuction procedures, thus an important factor for clinicians to consider preoperatively. We have also found age to be an independent risk factor for confirmed VTE in this patient population. This correlates with a recently published study from our group demonstrating that patients undergoing cosmetic surgical procedures were more likely to suffer a confirmed VTE if they were older than 40 years of age (0.13% vs 0.05%,  $P < 0.01$ ), and advancing age to be an independent risk factor for this outcome.<sup>45</sup> In addition, several population-based studies revealed that the incidence of VTE rises exponentially with age, and the risk approximately doubled with each decade of life after the age of 40.<sup>46-48</sup>

The differences in the clinical outcomes between genders have been studied in several surgical specialties, but not as extensively in the plastic surgery population, likely due to the fact that males represent only the small minority of the cases in most cosmetic surgery studies. However, over the last few years with the increase in popularity of aesthetic surgery among male patients,<sup>1</sup> the need to evaluate potential gender related risk factors for postoperative complications has become more relevant. In fact, male gender has been associated with a higher incidence of postoperative complications in patients undergoing aesthetic surgery, such as rhytidectomy,<sup>4,49-52</sup> abdominoplasty,<sup>53,54</sup>

and body contouring procedures.<sup>55,56</sup> In the present study, although female patients had a significantly higher complication rate when compared to males (2.5% vs 1.7%,  $P < 0.01$ ) on univariate analysis, there were no significant differences between the two genders on multivariate analysis. On the contrary, we found that females had a significantly lower risk of hematomas. This finding is consistent with the current literature for other plastic surgery procedures. For example, in patients undergoing rhytidectomy, several studies demonstrated that men have a higher incidence of postoperative hematomas.<sup>4,50-52,57</sup> Equally, Chong et al examined male patients in their prospective database who had undergone body-contouring surgery and found men to be more likely to have postoperative hematomas than women, with an odds ratio of 3.76.<sup>55</sup>

In recent years, obesity has become more prevalent in the United States, which was reflected in our analysis with a small increase in the percentage of patients with a BMI of 25 kg/m<sup>2</sup> or greater undergoing liposuction between 2008 and 2013 (56.4% vs 58.4%). Unfortunately, obesity does not only place the patient at higher risk of developing comorbid conditions, such as diabetes, hypertension, and cardiac disease, but also increases procedural morbidity and mortality rates.<sup>58,59</sup> It is not surprising that BMI has been stated to be a significant risk factor for postoperative complications in various surgical specialties including plastic surgery.<sup>49,54,58,60-64</sup> This has especially been shown with regard to infections, seromas, wound-related complications, and VTE.<sup>54,60,65-73</sup> These findings were confirmed in our study, with higher BMI found to be an independent predictor for major complications and for VTE, as well as surgical site infections as discussed previously. We detected a clear trend of a statistically significant increase in complication rates in overweight (2.7%), obese (3.3%), and morbidly obese (6.3%) patients compared with a 1.8% complication rate in patients with a BMI of 18.5 to 24.9 kg/m<sup>2</sup> (Figure 2A). Our analysis has also shown higher BMI to be an independent predictor for pulmonary complications, which could be attributed to larger volume liposuction in the obese population causing fluid changes that may affect the hemodynamic status of the patient and lead to pulmonary problems.

Over the last few decades, aesthetic surgical care in the United States has shifted from the hospital setting to outpatient facilities, with the majority of the procedures currently being performed in outpatient centers.<sup>74</sup> In 2000, the ASPS Board of Directors summoned the Task Force on Patient Safety in Office-based Surgical Facilities to promote patient safety, and emphasize that any financial savings or time gained when performing surgery in the outpatient setting is quickly lost if safety is compromised and complications are encountered.<sup>75,76</sup> As a result, several studies have been performed since that time demonstrating very low morbidity and mortality rates less than 1%,

thus suggesting that these facilities are safe for appropriately selected patients by qualified providers.<sup>75,77,78</sup> A large study reviewing the Internet-Based Quality Improvement and Peer Review Program developed by the American Association for Accreditation of Ambulatory Surgery Facilities (AAAASF) revealed 1378 significant sequelae (incidence of 0.33%) and 7 deaths (incidence of 0.0017%) from 411,670 procedures analyzed during a 2 year period (2001-2002).<sup>77</sup> Byrd et al published the experience from the Dallas Day Surgical Center and reported a complication rate of 0.7% with no deaths among 5316 consecutive cases completed between 1995 and 2000.<sup>75</sup> In our study, we have shown that the type of facility where the liposuction procedure is performed is an independent predictor of complications. Liposuction procedures performed in hospitals were associated with a higher risk of major complications compared to accredited surgical centers and office-based surgical suites with a RR of 1.36 (Figure 2B). These results may represent appropriate patient selection by plastic surgeons, where patients that are considered to be at “higher risk” for complications undergo surgery in a facility with a higher level of available care. Also, CosmetAssure database does not provide data on ASA classification and some major comorbidities, which might have affected surgeon’s choice on the type of the facility. Interestingly, we have also observed that when liposuction was combined with other procedures, these cases were more likely to be performed in hospitals (30.3% vs 22.6%), and less frequently to be performed in office-based surgical suites (14.1% vs 24.0%).

The concept of combined procedures in aesthetic plastic surgery has been around for decades, but received more attention recently for a variety of reasons including the latest advances in technology and surgical techniques combined with the introduction of new ideas such as “mommy makeover” and body contouring after massive weight loss.<sup>79,80</sup> This is also evident in our analysis, where liposuction was performed as a combined procedure in the majority of cases (62.9%). Indeed, combining procedures has numerous advantages, such as a single recovery period and reduced surgical costs with one anesthesia and facility fee. However, one of the main concerns of this approach is patient safety, as the cumulative effect of multiple procedures performed under a prolonged anesthesia time may increase the potential for complications. This is supported by our study, since we have shown that liposuction alone carried a major complication rate of 0.7% compared to 3.5% in combined procedures. In addition, the overall major complication rate increased from 0.7% with isolated liposuction to 3.2% with one additional procedure on one body region, and 4.5% with additional procedures on two or more body regions (Figure 2C). Further analysis demonstrated liposuction with abdominoplasty, liposuction with breast procedures, and liposuction with abdominoplasty

and breast procedures to be the most frequent procedure combinations at 22.4% (N = 6946), 14.9% (N = 4606), and 10.8% (N = 3364), respectively (Table 2). Several prior studies have examined the effect of combining liposuction, abdominoplasty and breast procedures on post-operative complications with mixed results. Neaman et al in a retrospective review of consecutive patients undergoing abdominoplasty over an 11-year period concluded that concurrent suction-assisted lipoplasty of the abdomen and flanks correlated to seroma formation, as well as minor and major complications.<sup>54</sup> Likewise, in a retrospective cohort study of 200 patients who underwent abdominoplasty with or without liposuction, liposuction of the flanks was found to be a significant predictor of seroma formation in abdominoplasty patients.<sup>81</sup> A study on lipoplasty procedures surveying ASAPS-member surgeons reported a mortality rate of 1 in 47,415 procedures, which increased to 1 in 7314 when liposuction was combined with other plastic surgery procedures, and rocketed to 1 in 3281 if liposuction was combined with abdominoplasty.<sup>5</sup> However, various authors have equally found no statistically significant differences in complication rates when comparing abdominoplasty with liposuction to abdominoplasty alone.<sup>60,82</sup>

Our analysis went one step further to examine the impact on complications when liposuction was added to other single cosmetic procedures, a common trend amongst plastic surgeons over the last few years. We have shown that the incidence of overall major complications, as well as individual complications except hematoma was higher when liposuction was performed with another cosmetic procedure when compared to isolated cosmetic procedures. It is unclear as to why fewer hematomas were observed when cosmetic procedures were done in conjunction with liposuction. However, one possible explanation for this observation is the effect of the liposuction infiltrate on the vasculature. Nowadays, it is standard practice to use a wetting solution, with epinephrine as one of the components of the infiltrate. Small amounts of epinephrine may travel through the tissues into adjacent areas or even remote areas via the systemic circulation resulting in vasoconstriction. Further research is required to investigate this interesting finding because CosmetAssure database does not identify the specific area of the body that liposuction is performed or the region that the hematoma occurs.

## Strengths and Limitations

This study, to the best of our knowledge, represents the largest single database series of liposuction patients to date. The CosmetAssure insurance database offers an important overall contribution to our understanding of the true incidence of complications and risk factors following liposuction surgery by collecting information in

a prospective fashion about the patient encounter and postoperative outcomes. It includes different practice settings (ie, office-based surgical suites, accredited surgical centers, and hospitals) across the United States, thus making the results generalizable to a wide variety of practice models. In addition, it accounts for the experience and training of the participating physicians by including only board-certified or board-eligible plastic surgeons; therefore, unlike other series, it avoids variability in complications attributed to the credentials of the health care provider. This is essential in the current era, where cosmetic operations are performed by a variety of physicians with different board affiliations. Most importantly, the outcomes examined are objective and accurate. CosmetAssure is a private insurance company with a vested interest in maintaining an accurate database for actuarial and audit purposes, and participating practices are subject to random audits to ensure compliance. All patients of a participating practice must enroll in the program, preventing selection of only high-risk patients, which may falsely inflate complication rates. Also, the program offers significant incentive to a surgeon reporting a complication, in form of payment of the claim. As a result, CosmetAssure has an advantage over databases or surveys that rely on voluntary self-report by potentially minimizing the under-reporting of complications. Moreover, this database has been previously cross-validated with other registries such as Tracking Operations and Outcomes for Plastic Surgeons (TOPS) and National Surgical Quality Improvement Program (NSQIP) database.<sup>83</sup>

While the CosmetAssure database has many advantages, a few of its limitations need to be discussed. The database does not include minor but clinically important complications such as skin necrosis, wound breakdown, or seroma. It also fails to capture some other undesirable sequelae of liposuction such as contour irregularities, skin laxity, or skin hyperpigmentation. All these minor problems are more common for this patient population and usually managed in the outpatient setting; however, they are critical in cosmetic outcomes as well as patient-perceived results. Despite the significant cost associated with the management of the major complications, it is possible that plastic surgeons may write it off or be reimbursed by patient's primary health insurance provider. Both of these scenarios are unlikely, but may result in under-reporting of major complications. Furthermore, CosmetAssure database lacks outcome specific details. For instance, it does not separate surgical site infections into different categories such as superficial, deep or wound dehiscence, which could have potentially allowed us to better understand the severity of this outcome. Also, patient reported outcomes and satisfaction surveys are not documented through the database making aesthetic

outcomes undetectable. In addition, the database itself has only recently started registering postoperative outcomes past 30 days, which could result in underreporting of our final outcomes. For example, even though postoperative VTE risk is believed to be at its highest in the first 2 weeks postoperatively, it may remain elevated for up to 12 months postoperatively.<sup>84-88</sup> As a result, some of these late VTE events would not be captured in the database resulting in underreporting of the outcome. Our analysis is restricted to the variables that are available in the database, which does not allow us to evaluate and account for all potential confounders. Perioperative factors that may play a role in the development of some of the complications such as antibiotic use, chemoprophylaxis and mechanical prophylaxis, intraoperative body temperature and blood pressure regulation, as well as operative times cannot be analyzed. Medications that can contribute to the risk of some of the complications examined such as immunosuppressive drugs, hormonal therapy, over the counter contraceptives, and anti-platelets or anticoagulants were not available in the database. Moreover, some important patient-specific characteristics and comorbid conditions that may affect the choice of the facility where the procedure will be performed and resultant outcomes, such as American Society of Anesthesiologists classification and history of blood disorders, were not provided and thus not examined. The database does not differentiate between the various liposuction techniques, which for example may involve different equipment or injectable solution or volume removed, and theoretically predispose patients to certain complications. Finally, while the database includes a wide variety of practices across the United States, it is limited to the participating centers and to a small fraction of eligible plastic surgeons in the country.

## CONCLUSIONS

Liposuction, one of the most popular cosmetic surgical procedures worldwide, is safe with a very low incidence of major complications in the hands of trained plastic surgeons. Hematoma, pulmonary dysfunction, surgical site infection, and VTE are the most common major complications, but still occur infrequently after liposuction. Several significant patient and procedure-related risk factors for major postoperative complications were identified including increasing age and BMI, procedures performed in a hospital setting, and combined procedures. Males were also more likely to suffer major hematomas following liposuction, and interestingly, hematomas decreased when liposuction was combined with other single cosmetic procedures compared to cosmetic procedures performed alone. Additional research is indicated to further



understand the effect of liposuction on hematoma rates when used as an adjunct to other cosmetic procedures. As expected, liposuction was most commonly performed in outpatient centers, but more cases were moved to the hospital environment when the procedure was done in conjunction with other cosmetic surgeries. Awareness of the major complications and the associated risk factors for this commonly performed procedure will provide considerable support to the plastic surgeons in the preoperative setting as it will allow for improved patient education as well as improved operative planning to enhance patient safety.

## Disclosures

Dr Grotting is a founder and shareholder of CosmetAssure (Birmingham, AL). He also receives book royalties from Quality Medical Publishing (St. Louis, MO) and Elsevier (New York, NY), and is a shareholder in Keller Medical, Inc. (Stuart, FL) and Ideal Implant, Inc. (Dallas, TX). The other authors declared no potential conflicts of interest with respect to the research, authorship, and publication of this article.

## Funding

The authors received no financial support for the research, authorship, and publication of this article.

## REFERENCES

1. Cosmetic surgery national data bank statistics. *Aesthet Surg J*. 2016;36(Suppl 1):1-29.
2. International Society of Aesthetic Plastic Surgery. *The International Survey on Aesthetic/Cosmetic Procedures Performed in 2015*. <http://www.isaps.org/news/isaps-global-statistics>. Accessed August 15, 2016.
3. Matarasso A, Levine SM. Evidence-based medicine: liposuction. *Plast Reconstr Surg*. 2013;132(6):1697-1705.
4. Gupta V, Winocour J, Shi H, Shack RB, Grotting JC, Higdon KK. Preoperative Risk Factors and Complication Rates in Facelift: Analysis of 11,300 Patients. *Aesthet Surg J*. 2016;36(1):1-13.
5. Hughes CE 3<sup>rd</sup>. Reduction of lipoplasty risks and mortality: an ASAPS survey. *Aesthet Surg J*. 2001;21(2):120-127.
6. Cárdenas-Camarena L. Lipoaspiration and its complications: a safe operation. *Plast Reconstr Surg*. 2003;112(5):1435-1441; discussion 1442.
7. Coleman WP, Hanke CW, Glogau RG. Does the specialty of the physician affect fatality rates in liposuction? A comparison of specialty specific data. *Dermatol Surg*. 2000;26(7):611-615.
8. Daane SP, Rockwell WB. Analysis of methods for reporting severe and mortal lipoplasty complications. *Aesthetic Plast Surg*. 1999;23(5):303-306.
9. Kim YH, Cha SM, Naidu S, Hwang WJ. Analysis of postoperative complications for superficial liposuction: a review of 2398 cases. *Plast Reconstr Surg*. 2011;127(2):863-871.
10. Lehnhardt M, Homann HH, Daigeler A, Hauser J, Palka P, Steinau HU. Major and lethal complications of liposuction: a review of 72 cases in Germany between 1998 and 2002. *Plast Reconstr Surg*. 2008;121(6):396e-403e.
11. Yoho RA, Romaine JJ, O'Neil D. Review of the liposuction, abdominoplasty, and face-lift mortality and morbidity risk literature. *Dermatol Surg*. 2005;31(7 Pt 1):733-743; discussion 743.
12. Flynn TC, Coleman WP 2<sup>nd</sup>, Field LM, Klein JA, Hanke CW. History of liposuction. *Dermatol Surg*. 2000;26(6):515-520.
13. Rohrich RJ, Beran SJ, Fodor PB. The role of subcutaneous infiltration in suction-assisted lipoplasty: a review. *Plast Reconstr Surg*. 1997;99(2):514-519; discussion 520-526.
14. Igra HLD. Avoiding complications. In: Hanke CWSG, ed. *Liposuction*. 1st ed. Philadelphia: Saunders; 2005:131-140.
15. Karmo FR, Milan MF, Silbergleit A. Blood loss in major liposuction procedures: a comparison study using suction-assisted versus ultrasonically assisted lipoplasty. *Plast Reconstr Surg*. 2001;108(1):241-247; discussion 248.
16. Lillis PJ. Liposuction surgery under local anesthesia: limited blood loss and minimal lidocaine absorption. *J Dermatol Surg Oncol*. 1988;14(10):1145-1148.
17. Gupta V, Parikh R, Nguyen L, et al. Is Office-Based Surgery Safe? Comparing Outcomes of 183,914 Aesthetic Surgical Procedures Across Different Types of Accredited Facilities. *Aesthet Surg J*. 2017;37(2):226-235.
18. Mangubat EA, Harbke C. Blood loss in liposuction surgery. In: Shiffman MA, Di Giuseppe A, eds. *Liposuction—Principles and Practice*. 1st ed. New York: Springer; 2006:347-352.
19. Commons GW, Halperin B, Chang CC. Large-volume liposuction: a review of 631 consecutive cases over 12 years. *Plast Reconstr Surg*. 2001;108(6):1753-1763; discussion 1764-1767.
20. Wollina U, Graf A, Hanisch V. Acute pulmonary edema following liposuction due to heart failure and atypical pneumonia. *Wien Med Wochenschr*. 2015;165(9-10):189-194.
21. Zakine G, Baruch J, Dardour JC, Flageul G. Perforation of viscera, a dramatic complication of liposuction: a review of 19 cases evaluated by experts in France between 2000 and 2012. *Plast Reconstr Surg*. 2015;135(3):743-750.
22. Dixit VV, Wagh MS. Unfavourable outcomes of liposuction and their management. *Indian J Plast Surg*. 2013;46(2):377-392.
23. Toledo LS, Mauad R. Complications of body sculpture: prevention and treatment. *Clin Plast Surg*. 2006;33(1):1-11, v.
24. Gingrass MK, Kenkel JM. Comparing ultrasound-assisted lipoplasty with suction-assisted lipoplasty. *Clin Plast Surg*. 1999;26(2):283-8; ix.
25. Beeson WH, Slama TG, Beeler RT, Rachel JD, Picerno NA. Group A streptococcal fasciitis after submental tumescent liposuction. *Arch Facial Plast Surg*. 2001;3(4):277-279.
26. Heitmann C, Czermak C, Germann G. Rapidly fatal necrotizing fasciitis after aesthetic liposuction. *Aesthetic Plast Surg*. 2000;24(5):344-347.
27. Fisher EJ, Gloster HM Jr. Infection with mycobacterium abscessus after Mohs micrographic surgery in an immunocompetent patient. *Dermatol Surg*. 2005;31(7 Pt 1):790-794.



28. Centers for Disease Control and Prevention (CDC). Rapidly growing mycobacterial infection following liposuction and liposculpture--Caracas, Venezuela, 1996-1998. *MMWR Morb Mortal Wkly Rep*. 1998;47(49):1065-1067.
29. Giannella M, Pistella E, Perciaccante A, Venditti M. Soft tissue infection caused by *Mycobacterium chelonae* following a liposculpture and lipofilling procedure. *Ann Ital Med Int*. 2005;20(4):245-247.
30. Meyers H, Brown-Elliott BA, Moore D, et al. An outbreak of *Mycobacterium chelonae* infection following liposuction. *Clin Infect Dis*. 2002;34(11):1500-1507.
31. Murillo J, Torres J, Bofill L, et al. Skin and wound infection by rapidly growing mycobacteria: an unexpected complication of liposuction and liposculpture. The Venezuelan Collaborative Infectious and Tropical Diseases Study Group. *Arch Dermatol*. 2000;136(11):1347-1352.
32. Anwar UM, Ahmad M, Sharpe DT. Necrotizing fasciitis after liposculpture. *Aesthetic Plast Surg*. 2004;28(6):426-427.
33. Barillo DJ, Cancio LC, Kim SH, Shirani KZ, Goodwin CW. Fatal and near-fatal complications of liposuction. *South Med J*. 1998;91(5):487-492.
34. Gibbons MD, Lim RB, Carter PL. Necrotizing fasciitis after tumescent liposuction. *Am Surg*. 1998;64(5):458-460.
35. Sharma D, Dalencourt G, Bitterly T, Benotti PN. Small intestinal perforation and necrotizing fasciitis after abdominal liposuction. *Aesthetic Plast Surg*. 2006;30(6):712-716.
36. Umeda T, Ohara H, Hayashi O, Ueki M, Hata Y. Toxic shock syndrome after suction lipectomy. *Plast Reconstr Surg*. 2000;106(1):204-207; discussion 208-9.
37. Kaoutzanis C, Gupta V, Winocour J, Shack B, Grotting JC, Higdon K. Incidence and Risk Factors for Major Surgical Site Infections in Aesthetic Surgery: Analysis of 129,007 Patients. *Aesthet Surg J*. 2017;37(1):89-99.
38. Miskiewicz K, Perreault I, Landes G, et al. Venous thromboembolism in plastic surgery: incidence, current practice and recommendations. *J Plast Reconstr Aesthet Surg*. 2009;62(5):580-588.
39. Newall G, Ruiz-Razura A, Mentz HA, Patronella CK, Ibarra FR, Zarak A. A retrospective study on the use of a low-molecular-weight heparin for thromboembolism prophylaxis in large-volume liposuction and body contouring procedures. *Aesthetic Plast Surg*. 30(1):86-95; discussion 96-97.
40. Prado A, Andrades P, Danilla S, Parada F. Perioperative thromboelastography analysis during suction-assisted lipectomy: a prospective cohort study. *J Plast Reconstr Aesthet Surg*. 2009;62(11):1453-1458.
41. Venturi ML, Davison SP, Caprini JA. Prevention of venous thromboembolism in the plastic surgery patient: current guidelines and recommendations. *Aesthet Surg J*. 2009;29(5):421-428.
42. Pannucci CJ, Barta RJ, Portschiy PR, et al. Assessment of postoperative venous thromboembolism risk in plastic surgery patients using the 2005 and 2010 Caprini Risk score. *Plast Reconstr Surg*. 2012;130(2):343-353.
43. Spring MA, Gutowski KA. Venous thromboembolism in plastic surgery patients: survey results of plastic surgeons. *Aesthet Surg J*. 2006;26(5):522-529.
44. Lubin MF. Is age a risk factor for surgery? *Med Clin North Am*. 1993;77(2):327-333.
45. Winocour J, Gupta V, Kaoutzanis C, et al. Venous Thromboembolism in the Cosmetic Patient: Analysis of 129,007 Patients. *Aesthet Surg J*. 2017;37(3):337-349.
46. Anderson FA Jr, Wheeler HB, Goldberg RJ, et al. A population-based perspective of the hospital incidence and case-fatality rates of deep vein thrombosis and pulmonary embolism. The Worcester DVT Study. *Arch Intern Med*. 1991;151(5):933-938.
47. Anderson FA Jr, Spencer FA. Risk factors for venous thromboembolism. *Circulation*. 2003;107(23 Suppl 1):I9-16.
48. White RH. The epidemiology of venous thromboembolism. *Circulation*. 2003;107(23 Suppl 1):I4-I8.
49. Abboushi N, Yezhelyev M, Symbas J, Nahai F. Facelift complications and the risk of venous thromboembolism: a single center's experience. *Aesthet Surg J*. 2012;32(4):413-420.
50. Baker DC, Aston SJ, Guy CL, Rees TD. The male rhytidectomy. *Plast Reconstr Surg*. 1977;60(4):514-522.
51. Baker DC, Stefani WA, Chiu ES. Reducing the incidence of hematoma requiring surgical evacuation following male rhytidectomy: a 30-year review of 985 cases. *Plast Reconstr Surg*. 2005;116(7):1973-1985; discussion 1986.
52. Grover R, Jones BM, Waterhouse N. The prevention of haematoma following rhytidectomy: a review of 1078 consecutive facelifts. *Br J Plast Surg*. 2001;54(6):481-486.
53. Winocour J, Gupta V, Ramirez JR, Shack RB, Grotting JC, Higdon KK. Abdominoplasty: Risk Factors, Complication Rates, and Safety of Combined Procedures. *Plast Reconstr Surg*. 2015;136(5):597e-606e.
54. Neaman KC, Armstrong SD, Baca ME, Albert M, Vander Woude DL, Renucci JD. Outcomes of traditional cosmetic abdominoplasty in a community setting: a retrospective analysis of 1008 patients. *Plast Reconstr Surg*. 2013;131(3):403e-410e.
55. Chong T, Coon D, Toy J, Purnell C, Michaels J, Rubin JP. Body contouring in the male weight loss population: assessing gender as a factor in outcomes. *Plast Reconstr Surg*. 2012;130(2):325e-330e.
56. Nemerofsky RB, Oliak DA, Capella JF. Body lift: an account of 200 consecutive cases in the massive weight loss patient. *Plast Reconstr Surg*. 2006;117(2):414-430.
57. Lawson W, Naidu RK. The male facelift. An analysis of 115 cases. *Arch Otolaryngol Head Neck Surg*. 1993;119(5):535-539; discussion 540.
58. de Jong RH. Body mass index: risk predictor for cosmetic day surgery. *Plast Reconstr Surg*. 2001;108(2):556-561; discussion 562.
59. Kreider JW, Hughes KC, Smeal D, Hirai T, Manders EK. Obesity. *Clin Plast Surg*. 1996;23(4):671-680; discussion 681.
60. Kim J, Stevenson TR. Abdominoplasty, liposuction of the flanks, and obesity: analyzing risk factors for seroma formation. *Plast Reconstr Surg*. 2006;117(3):773-779; discussion 780-781.
61. Neaman KC, Hansen JE. Analysis of complications from abdominoplasty: a review of 206 cases at a university hospital. *Ann Plast Surg*. 2007;58(3):292-298.

62. Gravante G, Caruso R, Araco A, Cervelli V. Infections after plastic procedures: incidences, etiologies, risk factors, and antibiotic prophylaxis. *Aesthetic Plast Surg*. 2008;32(2):243-251.
63. Mustoe TA, Park E. Evidence-based medicine: Face lift. *Plast Reconstr Surg*. 2014;133(5):1206-1213.
64. Momeni A, Heier M, Bannasch H, Stark GB. Complications in abdominoplasty: a risk factor analysis. *J Plast Reconstr Aesthet Surg*. 2009;62(10):1250-1254.
65. Hurvitz KA, Olaya WA, Nguyen A, Wells JH. Evidence-based medicine: Abdominoplasty. *Plast Reconstr Surg*. 2014;133(5):1214-1221.
66. Beer GM, Spicher I, Cierpka KA, Meyer VE. Benefits and pitfalls of vertical scar breast reduction. *Br J Plast Surg*. 2004;57(1):12-19.
67. Kompatscher P, von Planta A, Spicher I, et al. Comparison of the incidence and predicted risk of early surgical site infections after breast reduction. *Aesthetic Plast Surg*. 2003;27(4):308-314.
68. Serletti JM, Davenport MS, Herrera HR, Caldwell EH. Efficacy of prophylactic antibiotics in reduction mammoplasty. *Ann Plast Surg*. 1994;33(5):476-480.
69. Culver DH, Horan TC, Gaynes RP, et al. Surgical wound infection rates by wound class, operative procedure, and patient risk index. National Nosocomial Infections Surveillance System. *Am J Med*. 1991;91(3B):152S-157S.
70. O'Grady KF, Thoma A, Dal Cin A. A comparison of complication rates in large and small inferior pedicle reduction mammoplasty. *Plast Reconstr Surg*. 2005;115(3):736-742.
71. Abdollahi M, Cushman M, Rosendaal FR. Obesity: risk of venous thrombosis and the interaction with coagulation factor levels and oral contraceptive use. *Thromb Haemost*. 2003;89(3):493-498.
72. Masoomi H, Paydar KZ, Wirth GA, Aly A, Kobayashi MR, Evans GR. Predictive risk factors of venous thromboembolism in autologous breast reconstruction surgery. *Ann Plast Surg*. 2014;72(1):30-33.
73. Stein PD, Beemath A, Olson RE. Obesity as a risk factor in venous thromboembolism. *Am J Med*. 2005;118(9):978-980.
74. Horton JB, Janis JE, Rohrich RJ. MOC-PS(SM) CME article: patient safety in the office-based setting. *Plast Reconstr Surg*. 2008;122(3 Suppl):1-21.
75. Byrd HS, Barton FE, Orenstein HH, et al. Safety and efficacy in an accredited outpatient plastic surgery facility: a review of 5316 consecutive cases. *Plast Reconstr Surg*. 2003;112(2):636-641; discussion 642.
76. Iverson RE, ASPS Task Force on Patient Safety in Office-Based Surgery Facilities. Patient safety in office-based surgery facilities: I. Procedures in the office-based surgery setting. *Plast Reconstr Surg*. 2002;110(5):1337-1342; discussion 1343-1346.
77. Keyes GR, Singer R, Iverson RE, et al. Analysis of outpatient surgery center safety using an internet-based quality improvement and peer review program. *Plast Reconstr Surg*. 2004;113(6):1760-1770.
78. Morello DC, Colon GA, Fredricks S, Iverson RE, Singer R. Patient safety in accredited office surgical facilities. *Plast Reconstr Surg*. 1997;99(6):1496-1500.
79. Matarasso A, Smith DM. Combined breast surgery and abdominoplasty: strategies for success. *Plast Reconstr Surg*. 2015;135(5):849e-860e.
80. Pitanguy I, Ceravolo MP. Our experience with combined procedures in aesthetic plastic surgery. *Plast Reconstr Surg*. 1983;71(1):56-65.
81. Najera RM, Asheld W, Sayeed SM, Glickman LT. Comparison of seroma formation following abdominoplasty with or without liposuction. *Plast Reconstr Surg*. 2011;127(1):417-422.
82. Stevens WG, Cohen R, Vath SD, Stoker DA, Hirsch EM. Does lipoplasty really add morbidity to abdominoplasty? Revisiting the controversy with a series of 406 cases. *Aesthet Surg J*. 2005;25(4):353-358.
83. Alderman AK, Collins ED, Streu R, et al. Benchmarking outcomes in plastic surgery: national complication rates for abdominoplasty and breast augmentation. *Plast Reconstr Surg*. 2009;124(6):2127-2133.
84. Kearon C. Natural history of venous thromboembolism. *Circulation*. 2003;107(23 Suppl 1):I22-I30.
85. Pannucci CJ, Bailey SH, Dreszer G, et al. Validation of the Caprini risk assessment model in plastic and reconstructive surgery patients. *J Am Coll Surg*. 2011;212(1):105-112.
86. Planes A, Vochelle N, Darmon JY, Fagola M, Bellaud M, Huet Y. Risk of deep-venous thrombosis after hospital discharge in patients having undergone total hip replacement: double-blind randomised comparison of enoxaparin versus placebo. *Lancet*. 1996;348(9022):224-228.
87. Sweetland S, Green J, Liu B, et al.; Million Women Study collaborators. Duration and magnitude of the postoperative risk of venous thromboembolism in middle aged women: prospective cohort study. *BMJ*. 2009;339:b4583.
88. Young VL, Watson ME. The need for venous thromboembolism (VTE) prophylaxis in plastic surgery. *Aesthet Surg J*. 2006;26(2):157-175.