

The impact of surgical duration on plastic surgery outcomes

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Abstract

Background Historically, prolonged operative time has been associated with increased risk for morbidity and mortality. However, there is a paucity of clear data regarding the effect of longer operative times on outcomes in the field of plastic surgery. We endeavored to investigate the impact of operative time on postoperative morbidity and mortality in plastic surgery.

Methods Utilizing a multi-institutional surgical outcomes database spanning from 2006 to 2010, we identified 15,289 plastic surgery procedures. Operative time was tracked in 30-min increments. Multivariate logistic regression was utilized to investigate the relationship between operative time and primary outcomes of interest (medical complications, surgical complications, overall complications, and mortality). Subgroup analysis explored the relationship between operative time and outcomes in a homogenous *high-risk* cohort.

Results When progressing from the shortest surgical duration cohort to the longest, we see an incremental increase in overall complications (6.22 to 24.86 %), surgical complications (2.73 to 13.08 %), and medical complications (3.68 to 15.89 %). Furthermore, for every 30-min increase in operative time, there was a corresponding increased risk for 30-day overall complications (odds ratio (OR) 1.13, 95 % confidence interval (CI) 1.08–1.18), medical complications (OR 1.14, 95 % CI 1.06–1.23), and surgical complications (OR 1.14, 95 % CI 1.09–1.20). There was no significant association with 30-day mortality. Findings were substantiated through subgroup analysis.

Conclusions Drawing from data on over 15,000 plastic surgery procedures, we determined that increased operative time was associated with a higher risk of medical, surgical, and overall complications. As outcome measures take a more prominent role in the care of plastic surgery patients, these findings will advance patient education and practice management.

Level of Evidence: Level III, prognostic/risk study

Keywords Plastic surgery · Operative time · Outcomes · Complications

Introduction

Advancements in surgical techniques and anesthesia and medical management have increased the safety of plastic surgery procedures [1, 2]. While significant postoperative complications are infrequent in this field, the shifting landscape of healthcare policy has placed a greater emphasis on reducing postoperative adverse events [3–8].

It has been a common assumption that longer operative times correlate with a higher risk for adverse events [9–52]. Longer surgical duration may reflect higher procedural complexity and riskier patients, yet there may also be an inherent risk associated with longer operative times, independent of these other factors. Previous studies have considered the implications of greater surgical durations on plastic surgery patients. However, the exact impact of operative time on plastic surgery outcomes remains unclear as these noted analyses offer differing conclusions based on data derived from single institutions, specific procedures, or small sample sizes [9, 52–59]. A multi-institutional study would help clarify this important – and heretofore unanswered – question, yet no such analyses have been conducted to date. At present time, many large scale surgical outcomes databases exist that would allow for proper exploration of the relationship between operative time and outcomes [60–62]. We

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used a multi-institutional database to analyze the effects of surgical duration on postoperative 30-day mortality, as well as medical, surgical, and overall complications, after plastic surgery. It is our hope that the conclusions from this study will help enhance patient education and improve surgical safety.

Material and methods

Data source

We reviewed the National Surgical Quality Improvement Program database from 2006 to 2010 for all cases with “Plastics” recorded as their primary surgical specialty (a variable tracked in the dataset). The data used are drawn from over 240 institutions spanning 240 variables and de-identified to ensure patient anonymity. Any plastic surgery case without a recorded operative time was excluded.

Outcomes

We tracked four primary outcomes of interest: 30-day medical complications, surgical complications, overall complications, and mortality. A medical complication was defined as having one or more of the following events: pneumonia, unplanned intubation, pulmonary embolism, failure to wean from mechanical ventilation, progressive renal insufficiency, acute renal failure, urinary tract infection, peripheral nerve injury, stroke, coma, cardiac arrest, myocardial infarction, bleeding requiring a transfusion, deep venous thrombosis (DVT), and sepsis/septic shock. Surgical complications included one or more of the following events: superficial surgical site infection (SSI), deep SSI, organ/space SSI, wound disruption/dehiscence, and graft/flap/prosthesis failure. Overall complication was defined as having one or more of the aforementioned medical or surgical complications.

Statistical analysis

Patient demographics, clinical characteristics, and comorbidities were considered as potential independent variables. Demographic data included age, gender, and obesity (BMI > 30). Clinical characteristics included smoking, alcohol use (> 2 drinks a day), steroid use, radiotherapy within 90 days, chemotherapy within 30 days, previous operation within 30 days, DNR status, and functional health status prior to surgery. Comorbidities included diabetes, dyspnea, ventilator dependence, peripheral vascular disease, hypertension, chronic obstructive pulmonary disease (COPD), congestive heart failure (CHF), bleeding, previous percutaneous coronary intervention, prior cardiac surgery, prior transient ischemic attack, history of

cerebrovascular accident with and without residual neurological deficit, rest pain, renal failure, dialysis, impaired sensorium, weight loss, disseminated cancer, and American Society of Anesthesiologists (ASA) class 3 or 4. The duration of surgery—which is recorded as a continuous variable in the database—was divided into 30-min increments to create 13 categories. Categorical variables were analyzed using χ^2 tests, and continuous variables were analyzed using one-way ANOVA tests.

Multivariate logistic regression modeling was utilized to analyze the relationship between surgical time and the four primary outcomes. Individual variables with ≥ 10 event occurrences and $p \leq 0.20$ on bivariate analysis as well as noted clinical importance were included. Such variables included diabetes, hypertension, and obesity; the sum of relative value units was also incorporated into the regression model as a proxy for procedure complexity. Additional analyses with χ^2 tests were utilized for the overall complication and mortality cohorts. Additionally, C statistics for discrimination and Hosmer–Lemeshow tests for calibration were considered for goodness of fit. All analyses were performed using SPSS, version 21 (Chicago, IL).

Subgroup analysis

In an effort to analyze the impact of operative time on outcomes in a more homogenous population, a *high-risk* cohort was isolated by selecting all patients with hypertension, diabetes, and obesity. These patients were subsequently divided into hour increments of operative time (hours were utilized instead of minutes due to the smaller patient cohort). Similar to the overall population, chi-square tests were used to compare categorical variables, and one-way ANOVA tests were used for continuous variables. Multivariate regression models were also employed to assess surgical duration as an independent predictor of complications.

Results

A total of 15,289 patients underwent a tracked plastic surgery procedure within the database between 2006 and 2010. Each surgical duration category had at least 150 patients. Over three fourths of the patients had procedures lasting less than 3 h, with the highest frequency (17 %) falling in the 60–90-min range. There were 535 patients with a procedure length greater than 6 h. Patient demographics, clinical characteristics, and comorbidities varied across these surgical duration groupings, with the higher rates of comorbidities and high-risk clinical characteristics in cohorts with longer operative times. Acknowledging the differences between patient cohorts, significant preoperative risk factors were

incorporated into the multivariate regression models to reduce patient bias.

Overall, 6.50 % of the plastic surgery patients analyzed suffered from at least one complication. Specifically, 3.20 % of patients experienced a medical complication, and 4.00 % had a surgical complication. The 30-day mortality rate was low at 0.34 %. Overall complication rates, as shown in Table 1 and Fig. 1, trended upward from 6.22 % in the 0 to 30-min time cohort to nearly 25 % in the 6-h or longer grouping. Similarly, surgical complication rates increased from 2.73 to 13.08 %, and medical complications increased from 3.68 to 15.89 %. Mortality rates, which were notably low, remained stable over time. However, there was a spike in complication and mortality rates in the 0 to 30-min grouping. This observation was evaluated in greater detail through additional chi-square analysis.

Multivariate regression modeling was utilized to parse through these relationships and to control for confounding factors (Table 2). For every additional 30 min of operative time, patients had an increased risk of 30-day overall complications (odds ratio (OR) 1.13, 95 % confidence interval (CI) 1.08–1.18), medical complications (OR 1.14, 95 % CI 1.06–1.23), and surgical complications (OR 1.14, 95 % CI 1.09–1.20). There was no statistically significant association with 30-day mortality.

Chi-square testing was utilized to further examine possible causes for the complication spike noted in the shortest surgical duration grouping (less than 30 min). Analysis revealed higher rates of several comorbidities and risk factors in this specific cohort when compared to others. In detail, there was a higher prevalence of obesity, diabetes, known cancer, and bleeding disorders. These patients were also more likely to have had prior cardiac surgery or a prior operation within 30 days of their index procedure.

Patients with a postoperative complication from any surgical duration grouping had higher rates of preoperative steroid use, diabetes, hypertension, COPD, CHF, dialysis, bleeding disorders, previous coronary intervention or cardiac surgery, peripheral vascular disease, hemiplegia, transient ischemic attack, open wound infection, obesity, and emergency cases (Table 3). Thirty one of the 52 patients who died within 30 days had procedures lasting less than 60 min. These patients had significantly higher rates of preoperative high-risk characteristics, with the most common being hypertension, known wound infection, and ASA class 3 or 4. Those who died also had higher rates of postoperative complications, including organ space infections, sepsis, and unplanned intubations (Table 4).

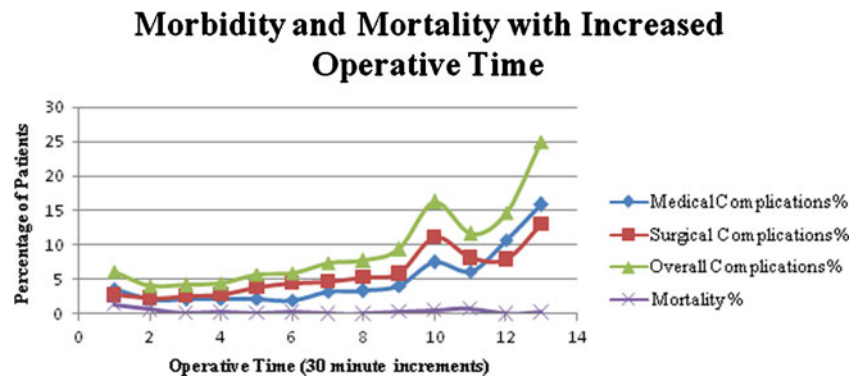
Subgroup analysis

Operative time may be best examined in a homogenous population where differences in baseline patient health would be less likely to influence postoperative outcomes. Therefore, a

Table 1 Overall complication, surgical complication, medical complication, and mortality rates, stratified by surgical duration

Surgical time (min)	0–30	30–60	60–90	90–120	120–150	150–180	180–210	210–240	240–270	270–300	300–330	330–360	≥360
<i>N</i>	1,061	2,525	2,626	2,163	1,738	1,488	1,096	779	513	332	257	176	535
30-day outcomes													
Overall complications	6.22 %	4.04 %	4.23 %	4.53 %	5.75 %	5.98 %	7.39 %	7.70 %	9.36 %	16.27 %	11.67 %	14.77 %	24.86 %
Surgical complications	2.73 %	2.30 %	2.55 %	2.77 %	3.91 %	4.44 %	4.65 %	5.26 %	5.85 %	11.14 %	8.17 %	7.95 %	13.08 %
Medical complications	3.68 %	2.10 %	2.10 %	2.22 %	2.19 %	2.02 %	3.28 %	2.95 %	4.09 %	7.53 %	6.23 %	10.80 %	15.89 %
Mortality	1.41 %	0.63 %	0.15 %	0.23 %	0.12 %	0.20 %	0.00 %	0.00 %	0.39 %	0.60 %	0.78 %	0.00 %	0.19 %

Fig. 1 Morbidity and mortality rates across operative time



total of 344 *high-risk* patients were isolated from the plastic surgery population. These patients were categorized into one of seven surgical duration cohorts, with operative time categorized into hour increments. Analysis revealed an increase in total, surgical and medical complication rates when progressing from the shortest surgical time category to the longest. Total complication rates increased from 3.37 to 53.33 % (Fig. 2), surgical complication rates rose from 1.12 to 20.00 %, and medical complications increased from 3.37 to 46.67 %. Multivariate regression models substantiated findings from the overall population, as operative time was associated with a 1.66 odds ratio for total complications (Table 5).

Discussion

As governmental scrutiny of healthcare increases, the need to reduce hospital-associated complications is becoming ever more apparent [63, 64]. In this matter, our ability to determine risk factors for postoperative complications and ultimately prevent such occurrences is vital. Great attention should therefore be given to the circumstances that predispose patients to adverse events following plastic surgery procedures. While a myriad of studies have discussed the putative relationship between operative time and surgical complications, those concentrating on plastic surgery have presented a narrow focus with data derived from a single operation or procedure and/or centered on the outpatient setting [9, 52–59]. Here, we provide the largest examination of operative time and postoperative complications to date using a validated, multicenter surgical outcomes database.

Nine hundred and ninety three (6.50 %) of the 15,289 plastic surgery patients extracted from the database suffered a postoperative complication. Only 52 patients died in the

30 days following their plastic surgery procedure. While the aforementioned findings substantiate the low morbidity and mortality rates previously associated with plastic surgery, they also show a notable trend toward increasing complication rates with increasing surgical time. Specifically, overall complication rates quadrupled when progressing from operations lasting less than 30 min to procedures lasting over 6 h. Rates for surgical and medical complications increased in a similar fashion from 2.73 to 13.08 % and from 3.68 to 15.89 %, respectively. Furthermore, when looking at Fig. 1, the 4.5-h mark appears to be an inflection point in which we see a steeper increase in complication rates with surgical durations over that time. Such an increase was likely influenced by a number of factors, including patient characteristics and procedure complexity, in addition to operative time itself. This is substantiated by the notable increase in comorbidities in the higher surgical duration cohorts. Additionally, the steep increase in complication rates following 4.5 h of operative time is partially attributable to the fact that minor—and therefore less morbid—procedures are often shorter in duration. Therefore, more detailed subgroup and regression analyses were performed to elucidate the influence of operative time on surgical outcomes.

Acknowledging the slight complication and mortality rate spike in the 0 to 30-min surgical duration cohort, additional analysis was performed. We found that individuals in the shortest time category were generally sicker than their higher surgical duration counterparts. These patients had more comorbidities and high-risk clinical characteristics than patients in other time cohorts—presumably putting them at greater risk for complications and death. Moreover, the less than optimal baseline health seen in these individuals could have caused their original operation to be cut short, leading to a quicker operation than anticipated. Poor patient health status

Table 2 Multivariate regression analysis

Overall complications		Surgical complications			Medical complications			Mortality		
OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI	
1.13*	1.08 1.18	1.14*	1.09 1.20	1.14*	1.06 1.23	0.92	0.77 1.10			

* $p < 0.05$; denotes significant value

Table 3 Demographic data and clinical characteristics of patients with and without complications

Characteristics	No complication n=14,291	Complication n=998	p value
Age >50	44.94 %	43.25 %	<0.001*
Gender (%male)	21.32 %	30.36 %	<0.001*
Obesity	32.66 %	47.19 %	<0.001*
Clinical characteristics (%)			
Smokers	18.00 %	20.64 %	0.036*
Alcohol use	2.06 %	1.50 %	0.224
Steroid use	1.47 %	5.01 %	<0.001*
Previous OP <30 days	3.66 %	15.03 %	<0.001*
Emergency case	2.54 %	3.95 %	<0.001*
Comorbidities (%)			
Diabetes	7.43 %	20.54 %	<0.001*
Dyspnea	3.60 %	10.32 %	<0.001*
Hypertension	26.33 %	42.59 %	<0.001*
COPD	1.60 %	5.21 %	<0.001*
Congestive heart failure	0.15 %	1.80 %	<0.001*
Dialysis	0.42 %	3.31 %	<0.001*
Bleeding disorders	1.62 %	4.81 %	<0.001*
Percutaneous coronary intervention	1.92 %	4.31 %	<0.001*
Previous cardiac surgery	2.24 %	6.31 %	<0.001*
Revascularization for PVD	0.90 %	4.11 %	<0.001*
Hemiplegia	0.34 %	1.50 %	<0.001*
Transient ischemic attack	1.02 %	2.91 %	<0.001*
Open wound infection	8.93 %	31.06 %	<0.001*
ASA level 3 or 4	21.83 %	53.13 %	<0.001*

* $p < 0.05$; denotes significant value

may also serve to partially explain complications in other surgical duration cohorts. We agree that patient characteristics do contribute to the cumulative risk for incurring a postoperative complication. However, we contend that operative time and the invasive nature of surgery can impart their own independent risk for complications as well—a theory best analyzed through risk-adjusted multivariate logistic regression.

Adjusted multivariable regression revealed a significant increased risk for overall, surgical, and medical complications with operative time; no significant relationship between surgical duration and mortality was noted. Such analysis shows that operative time does hold an inherent risk for complications. While there were known discrepancies between the cohorts with and without complications, our regression models were adjusted for significant preoperative risk factors—thereby reducing patient bias. Additionally, recognizing that surgical time may be considered a proxy for procedure complexity, the sum of the relative value units (RVUs) was included in the regression model.

Table 4 Preoperative comorbidities and postoperative complications in patients who died within 30 days

Characteristics	No death n=15,237	Death n=52	p value
Age >50	44.66 %	84.62 %	<0.001*
Clinical characteristics (%)			
DNR	0.20 %	11.54 %	<0.001*
Ventilator use	0.24 %	9.61 %	<0.001*
Steroid use	1.65 %	15.38 %	<0.001*
Previous OP <30 days	4.31 %	30.77 %	<0.001*
Emergency case	2.63 %	9.62 %	0.002*
Comorbidities (%)			
Diabetes	8.18 %	40.48 %	<0.001*
Dyspnea	3.96 %	28.85 %	<0.001*
Hypertension	27.22 %	78.85 %	<0.001*
COPD	1.79 %	15.38 %	<0.001*
Congestive heart failure	0.24 %	9.62 %	<0.001*
Dialysis	0.55 %	17.31 %	<0.001*
Bleeding disorders	1.79 %	15.38 %	<0.001*
Percutaneous coronary intervention	2.02 %	19.23 %	<0.001*
Previous cardiac surgery	2.43 %	23.07 %	<0.001*
Revascularization for PVD	1.05 %	17.31 %	<0.001*
Myocardial infarction	0.32 %	5.77 %	<0.001*
Esophageal varices	0.01 %	3.85 %	<0.001*
Hemiplegia	0.40 %	5.77 %	<0.001*
Transient ischemic attack	1.11 %	11.54 %	<0.001*
Open wound infection	10.19 %	65.38 %	<0.001*
ASA level 3 or 4	23.48 %	90.38 %	<0.001*
Ascites	0.06 %	3.85 %	<0.001*
Cerebrovascular accident/stroke	2.54 %	9.62 %	<0.001*
Cancer	0.47 %	17.31 %	<0.001*
Postoperative complications (%)			
Deep surgical site infection	0.79 %	5.77 %	<0.001*
Superficial surgical site infection	1.90 %	0.00 %	0.003*
Organ/space surgical site infection	4.31 %	30.77 %	<0.001*
Wound disruption	0.63 %	0.00 %	0.004*
Pneumonia	0.29 %	21.15 %	<0.001*
Unplanned intubation	0.18 %	26.92 %	<0.001*
Pulmonary embolism	0.12 %	1.92 %	<0.001*
Ventilator	0.32 %	23.08 %	<0.001*
Acute renal failure	0.07 %	3.85 %	<0.001*
Cerebrovascular accident	0.05 %	7.69 %	<0.001*
Coma	0.00 %	7.69 %	<0.001*
Cardiac arrest	0.03 %	17.31 %	<0.001*
Myocardial infarction	0.06 %	3.85 %	<0.001*
DVT	0.25 %	3.85 %	<0.001*
Sepsis or septic shock	1.10 %	25.00 %	<0.001*

* $p < 0.05$; denotes significant value

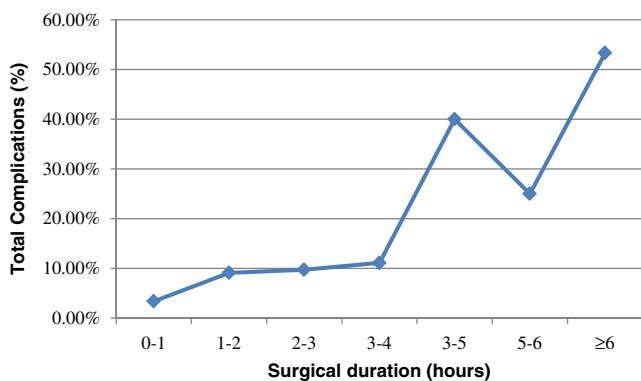


Fig. 2 Complication rates across operative time in *high-risk* patients

These measures helped ensure that the notably high odds for complications associated with operative time were independent of potential confounding variables.

Our analysis revealed that plastic surgery patients had a 13 % increase in their risk for complications with every 30-min increase in operative time. Other factors such as patient characteristics and surgical complexity held a separate and independent impact on outcomes. The reasoning behind surgical duration's role as an independent predictor of complications is certainly multifactorial, yet the invasive nature of surgery may be a key contributor [41]. Plastic surgery often focuses on the soft tissue spaces, and an incision through the epidermis exposes previously protected spaces to the bacteria-ridden outside environment. Sterile protocols and preoperative antibiotics have helped reduce surgical infections; however, the longer an operative site is open to the elements, the more likely bacterial contamination will occur. Other factors, including the associated stress of surgery, are thought to be contributors to the increasing complication rates with longer operations [43, 65, 66]. The surgical stress response can alter cytokine levels, change sympathetic tone, and lead to catecholamine surges—all of which may predispose patients to complications [67, 68]. Additionally, stress can lead to myocardial ischemia, decreased pulmonary efficiency, and hyperglycemia [69–72]. Such factors may be more likely to occur with longer operations and could delay healing, prolong latency to recovery, and increase the risk for surgical and medical adverse events.

The limitations of the study are mostly related to the limitations of the database utilized. First, our outcomes were

Table 5 Operative time as a predictor of total complications in *high-risk* patients. *High-risk* is defined as any patient with known diabetes, hypertension, and obesity

	OR	95 % CI		<i>p</i> value
Operative time (h)	1.658	1.361	2.02	<0.001

* $p < 0.05$; denotes significant value

tracked up until 30 days following the index operation, precluding our ability to evaluate complications beyond this time frame. Second, multivariate regression in the context of a large dataset can lead to statistical overfitting. However, we attempted to resolve this utilizing clinical judgment and a bivariate screen. Third, it is difficult to fully isolate surgical time for analysis. However, we attempted to control patient bias and case complexity by incorporating significant preoperative variables and controlling for RVUs in our regression. Nonetheless, the database we used offers profound strengths in clinical outcomes analysis, and the advantages of this study outweigh the aforementioned limitations.

Conclusion

Using a multi-institutional surgical outcomes database to analyze over 15,000 plastic surgery cases, we found that longer surgical times were related to a significantly increased risk for overall, medical, and surgical complications. These results offer valuable insight on the operative management of plastic surgery patients.

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Conflict of interest None

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