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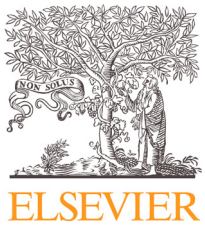

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Nationwide analysis of plastic and reconstructive procedural volume in the United States during the COVID-19 pandemic

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Summary *Introduction:* This study aims to define the impact of the novel Coronavirus Disease 2019 (COVID-19) pandemic on the volume of common plastic and reconstructive procedures in the United States.
Methods: TrinetX is a national, federated database that was utilized in surveying plastic and reconstructive procedural volumes among 53 Healthcare organizations (HCO) between March 2018 and May 2021. This timeframe was divided into pre-pandemic (March 2018 to February 2020) and pandemic periods (March 2020 to May 2021). Each period was then sub-divided into four seasons of the year and the mean monthly procedural volume per HCO was compared. A student's t-tests comparing pre-pandemic and pandemic seasonal mean procedural volumes were used for statistical analysis.
Results: A total of 366,032 patient encounters among 53 HCO were included. The average seasonal volume per HCO of all procedures reduced from 872.11 procedures during pre-pandemic seasons to 827.36 during pandemic seasons. Spring 2020 vol declined for most procedures as 15 of 24 (63%) assessed procedure categories experienced statistically significant decreases. Spring 2021 experienced rebounds with 15 of 24 (63%) assessed procedures showing statistically significant increases.

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Conclusion: During the pandemic period, the average procedural volume per HCO of 14 procedure categories was significantly less than the pre-pandemic average procedural volume. Overall, an inverse relationship was observed between novel COVID-19 cases and plastic and reconstructive surgery procedure volumes in the United States.
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Introduction

By the first quarter of 2020, the novel Coronavirus Disease 2019 (COVID-19) pandemic had substantially affected the functional capacity of healthcare organizations (HCO) worldwide. Given the increased risk of transmission through close contact and aerosolized transmission, surgical services were heavily impacted[1]. According to the American Hospital Association, estimates of the financial losses from March 2020 – June 2020 exceeded US$202 billion, of which US$161 billion was secondary to canceled surgical procedures[2]. The American College of Surgeons (ACS) published initial recommendations for the cessation of all elective procedures in March 2020[3]. Immediately, state, federal, and specialty-specific guidelines were issued[4-7]. Specific plastic and reconstructive professional organization guidance was published by the American Society of Plastic Surgeons (ASPS). Outlined in their March 2020 correspondence, ASPS initially cautioned its members to only provide care deemed "urgent or emergent" based on personal discretion[8]. Preliminary analysis during this time revealed plastic and reconstructive surgery to be among the three surgical services that witnessed the largest decrease in total operating room (OR) volume from March-June 2020 compared to the corresponding period in 2019[9].

As of December 2020, current ASPS recommendations advise members to consult with the hospital, local, county, state, and regional regulatory bodies regarding elective surgeries[10]. These regulations, however, have remained highly variable across time and by region since the onset of the COVID-19 pandemic. Plastic and reconstructive surgery, with many elective and non-emergent procedures[11], was particularly vulnerable to COVID-19 related barriers. Furthermore, the significant role of elective admissions and procedures in maintaining health system revenue viability[12,13] poses significant financial loss to all health system groups irrespective of their size.

Preliminary feedback from the American Council of Academic Plastic Surgeons (ACAPS) self-reporting member surgeons corroborates the predicted initial limitation of plastic and reconstructive operational volume[14]. The longer-term impact of the COVID-19 pandemic on specific plastic and reconstructive procedures, however, remains unquantified in the literature. Therefore, the objective of this study was to compare the common plastic and reconstructive procedural volumes in the United States from 2018 to 2021. years.

Materials and methods

TrinetX (Cambridge, MA) is a national, federated database that was utilized in this retrospective study. Electronic medical records reported between March 2018 and May 2021 were analyzed. This platform consists of aggregate, de-identified electronic health records (EHR) of $>$ 72 million patient records reported by 53 continually updating HCOs, with most HCO-provided data dating back to 2014[15] because the exclusion of protected personal health information in the database ensure data compliance with the Health Insurance Portability and Accountability Act (HIPAA). Previous literature in plastic surgery has reported on data obtained from TrinetX.[16]

A literature review was conducted to identify a representative sample of the most common plastic and reconstructive procedures nationally [17-20]. TrinetX database was queried for the associated Current Procedural Terminology (CPT) codes (Table 1) of both inpatient and outpatient operations. Monthly case volume as well as the corresponding number of reporting HCOs was compiled during the study period. To account for procedure-specific changes in the number of reporting HCO, monthly mean operative volume per HCO was calculated on a CPT-specific level as well as in aggregate. The monthly CPT-specific volumes per HCO were clustered chronologically to determine average volumes for three-month seasons throughout the study period. To provide a more meaningful baseline of pre-pandemic volume, a combination of the 2018 and corresponding 2019 figures was used.

The following seasons were analyzed: Spring 2020 (March-May 2020), summer 2020 (June-August 2020), fall 2020 (September-November 2020), winter 2020/2021 (December 2020-February 2021), spring 2021 (March-May 2021) as well as their pre-pandemic analogs. Finally, an aggregate of the total pandemic period (March 2020- May 2021) was compared to the corresponding figures in pre-pandemic timeframes. Descriptive analyses were performed and comparisons were made using a student's *t*-test. Statistical analysis was performed using Microsoft Excel with a predetermined level of significance set at $p < 0.05$ (Microsoft Inc., Washington, USA).

Results

A total of 366,032 plastic and reconstructive procedures from 53 HCO during March 2018 - May 2021 were included in the current study. The analyzed procedures with the highest volume over the entire review period (March 2018 - May 2021) were neuroplasty and/or transposition; median nerve at the carpal tunnel with an aggregate operative volume of 51,395. Neuroplasty and/or transposition- median nerve at carpal tunnel also showed the highest seasonal mean volume per HCO for four of the five pandemic seasons analyzed. Only during spring 2020 the seasonal mean of neu-

Table 1 30 of the most commonly performed plastic and reconstructive procedures along with their associated Current Procedural Terminology (CPT) codes.

CPT Codes	Procedure Names
11,043	Debridement, muscle and/or fascia (includes epidermis, dermis, and subcutaneous tissue, if performed); first 20 sq cm or less
11,044	Debridement, bone (includes epidermis, dermis, subcutaneous tissue, muscle and/or fascia, if performed); first 20 sq cm or less
11,402	Excision, benign lesion including margins, except skin tag (unless listed elsewhere), trunk, arms or legs; excised diameter 1.1 to 2.0 cm
11,602, 11,603	Excision, malignant lesion including margins, trunk, arms, or legs; excised diameter 1.1 to 2.0 cm, Excision, malignant lesion including margins, trunk, arms, or legs; excised diameter 2.1 to 3.0 cm
14,060, 14,061	Adjacent tissue transfer or rearrangement, eyelids, nose, ears and/or lips
13,131, 13,132	Repair, complex, forehead, cheeks, chin, mouth, neck, axillae, genitalia, hands and/or feet; 1.1 cm to 2.5 cm-7.5cm
14,300/14,301	Adjacent tissue transfer or rearrangement, any area; defect 30.1–60.0 cm2
15,100	Split-thickness autograft, trunk, arms, legs; first 100 cm2 or less, or 1% of body area of infants and children
15,240	Full-thickness graft, free, including direct closure of donor site, forehead, cheeks, chin, mouth, neck, axillae, genitalia, hands, and/or feet; 20 cm2 or less
15,271,15,272, 15,273, 15,274	Application of skin substitute graft to trunk, arms, legs, total wound surface area up to 100 sq cm, Application of skin substitute graft to trunk, arms, legs, total wound surface area greater than or equal to 100 sq cm
15,736	Muscle, myocutaneous, or fasciocutaneous flap; Upper extremity
15,738	Muscle, myocutaneous, or fasciocutaneous flap; lower extremity
15,756	Muscle or myocutaneous free flap with microvascular transfer
15,830	Excision, excessive skin and subcutaneous tissue (includes lipectomy); abdomen, infraumbilical panniculectomy
15,931, 15,933, 15,934, 15,935, 15,936, 15,937	Excision, sacral pressure ulcer
15,840, 15,841, 15,842, 15,845	Facial nerve paralysis graft
42,890, 42,892, 42,894	Limited pharyngectomy, Reconstruction of pharyngeal wall closure with flap or flap with microvascular anastomosis, Resection of lateral pharyngeal wall or pyriform sinus direct closure
19,325	Mammaplasty, augmentation; with the prosthetic implant
19,316	Mastopexy
19,318	Reduction mammaplasty
19,357, 19,342	Prosthetic breast reconstruction
19,361, 19,364, 19,367, 19,368	Autologus breast reconstruction
19,380	Revision of reconstructed breast
15,756, 15,757, 15,758, 20,969	Free flap procedures
15,922, 15,934, 15,936, 15,944, 15,945, 15,946, 15,956	Pressure ulcer repair
25,000	Incision, extensor tendon sheath, wrist (eg, de Quervain's disease)
26,615	Open treatment of metacarpal fracture, single, includes internal fixation, when performed, each bone
30,400, 30,410, 30,420	Rhinoplasty, primary
64,708,64,712,64,713, 64,714	Neuroplasty, major peripheral nerve, arm or leg, open
64,721	Neuroplasty and/or transposition; median nerve at the carpal tunnel

roplasty and/or transposition- median nerve at the carpal tunnel was not the highest average seasonal procedure volume per HCO.

Over the entirety of the five pandemic periods analyzed, almost every procedure's seasonal mean volume differed from pre-pandemic figures. Spring 2020 exhibited the most decreases (50%) in procedural volume compared to any other season with 15 statistically significant reductions. Meanwhile, the largest count of statistically significant increases in procedure volume (15/30) was documented in spring 2021. The seasonal mean volume over the aggregate March 2020 – May 2021 period of 10 procedures differed from aggregate March 2018 – February 2020 figures by a statistically significant amount (Table 5).

Spring 2020

The first season included in our analysis, spring 2020, showed a decrease in most mean procedural volumes per HCO relative to the 2018/2019 counterparts (Table 2). On a procedure-specific level, 15 of 24 (63%) procedures experienced a statistically significant reduction in volume, with the largest significant decreases experienced in excision, benign lesion including margins, except skin tag (unless listed elsewhere), trunk, arms or legs; excised diameter 1.1 to 2.0 cm (51%, $p < 0.00039$), excision, excessive skin and subcutaneous tissue (includes lipectomy); abdomen, infraumbilical panniculectomy (52%, $p < 0.0014$), reduction mammoplasty (46%, $p < 0.0013$), and revision of reconstructed breast (48%, $p < 0.0042$). Repair, complex, forehead, cheeks, chin, mouth, neck, axillae, genitalia, hands and/or feet; 1.1 cm to 2.5 cm-7.5 cm had the highest aggregate operative volume per HCO across the season with ~68 operations per HCO from March-May 2020. No statistically significant increases in mean procedural volume per HCO were observed during March-May 2020.

Summer 2020/ FALL 2020

The majority of procedures (21/30) saw a decline in volume for summer 2020, no decrease was found statically significant (Table 3). On a procedure-specific level, none of the fall 2020 vol changed by a statistically significant amount compared to pre-pandemic figures (Table 3). There were seven decreases in volume, none of which were statistically significant (Table 3).

Winter 2020/2021

Fall 2020 vol changes from pre-pandemic figures were broadly similar to those of winter 2020/2021. On a procedure-specific level, five changes were statistically significant (Table 3). There were two significant decreases: repair, complex, forehead, cheeks, chin, mouth, neck, axillae, genitalia, hands and/or feet- 1.1 cm to 2.5 cm-7.5 cm (26%, $p < 0.001$); and mastopexy (17%, $p < 0.037$). Further, three procedures muscle, namely myocutaneous, or fasciocutaneous- upper extremity (34%, $p < 0.050$); full-thickness graft, free, including direct closure of donor site, forehead, cheeks, chin, mouth, neck, axillae, genitalia, hands, and/or feet- 20 cm^2 or less (19%, $p < 0.027$); and free flap procedures (24%, $p < 0.026$) demonstrated a statistically significant increase in volumes.

Spring 2021

The final season included in our analysis, spring 2021, revealed 16 statistically significant changes with 15 of the 16 changes (94%) being statistically significant increases in mean procedural volumes per HCO relative to the 2018/2019 counterparts (Table 4). The largest of these volume increases were in excision, sacral pressure ulcer (44%, $p < 0.030$); full-thickness graft, free, including direct closure of donor site, forehead, cheeks, chin, mouth, neck, axillae, genitalia, hands, and/or feet; 20 cm^2 or less (41%, $p < 0.0032$) and rhinoplasty, primary (46%, $p < 0.00030$). Only one of the operations significantly declined in volume during this time frame: revision of reconstructed breast decreased by a statistically significant amount (17%, $p < 0.023$).

Discussion

The current study retrospectively reviews a large national cohort to analyze trends in operative case volume in plastic reconstructive surgery during the COVID-19 pandemic. Seasonal analysis was performed to achieve an iterative evaluation of fluctuations in plastic and reconstructive surgery volume. To the best of our knowledge, this is the first pandemic-related analysis of national operative volume in the subspecialty to date in the US. The database utilized is continuously updated by numerous HCOs generates insights into obstacles to more patient-specific plastic and reconstructive care, providing more individualized implications for future healthcare delivery as we return to normality.

This retrospective study demonstrates a significant decline in the gross volume of plastic and reconstructive procedures during the months immediately following the start of the COVID-19 pandemic. Comparison of spring 2020 means procedural volumes per HCO to corresponding pre-pandemic figures suggests an accumulation of unmet need for plastic and reconstructive care during the pandemic. The creation of these 'backlogs' on a much smaller scale has been elucidated well in current literature analyzing elective procedures in several specialties [21-24]. Likewise, the similarity between spring 2018 and spring 2019 seasonal average procedural volumes per HCO lends credibility to the assumption of year-on-year stability of demand for plastic surgery procedures. Resultantly, the decline in mean procedural volumes per HCO in spring 2020 reflects an inability of plastic surgeons to provide surgical care for their patients due to both safety concerns and diverted healthcare resources in response to the COVID-19 pandemic. The mean seasonal procedure volume per HCO of repair, complex, forehead, cheeks, chin, mouth, neck, axillae, genitalia, hands and/or feet- 1.1 cm to 2.5 cm-7.5 cm, for example, decreased by a statistically significant amount relative to corresponding pre-pandemic figures during four of the five seasons analyzed. Collectively, this suggests an unmet need for plastic

Table 2 Seasonal mean procedural volumes per HCO and associated standard deviation (SD) for spring 2020 (pandemic) and spring 2018/2019 (pre-pandemic) along with the change (in%) and statistical significance of the change (denoted by *p*-value).

CPT CODES	MARCH TO MAY - 2020 VS 2018/2019 SEASONAL MEAN PROCEDURAL VOLUME PER HCO			
	Pandemic Mean (SD)	Pre-pandemic Mean (SD)	Percent Change (%)	P-value
Debridement, muscle and/or fascia (includes epidermis, dermis, and subcutaneous tissue, if performed); first 20 sq cm or less	22.3 (2)	21.2 (3)	5.44%	0.568690
Debridement, bone (includes epidermis, dermis, subcutaneous tissue, muscle and/or fascia, if performed); first 20 sq cm or less	10.2 (1.4)	11.5 (1.7)	−10.99%	0.313187
Excision, benign lesion including margins, except skin tag (unless listed elsewhere), trunk, arms or legs; excised diameter 1.1 to 2.0 cm	9.1 (3.8)	18.4 (0.4)	−50.51%	0.000388
Excision, malignant lesion including margins, trunk, arms, or legs; excised diameter 1.1 to 2.0 cm, excision, malignant lesion including margins, trunk, arms, or legs; excised diameter 2.1 to 3.0 cm	15.5 (7)	22.5 (1.5)	−31.24%	0.040044
Adjacent tissue transfer or rearrangement, eyelids, nose, ears and/or lips	11.6 (3.9)	17.7 (0.9)	−34.28%	0.006215
Repair, complex, forehead, cheeks, chin, mouth, neck, axillae, genitalia, hands and/or feet; 1.1 cm to 2.5 cm-7.5cm	22.8 (7.3)	37.3 (2)	−38.85%	0.001879
Adjacent tissue transfer or rearrangement, any area; defect 30.1–60.0 cm2	9.2 (2.7)	11.1 (1.3)	−17.26%	0.187133
Split-thickness autograft, trunk, arms, legs; first 100 cm2 or less, or 1% of body area of infants and children	9.1 (1.3)	11 (0.9)	−17.57%	0.033898
Full-thickness graft, free, including direct closure of donor site, forehead, cheeks, chin, mouth, neck, axillae, genitalia, hands, and/or feet; 20 cm2 or less	3.8 (0.7)	4.4 (0.4)	−13.86%	0.141859
Application of skin substitute graft to trunk, arms, legs, total wound surface area up to 100 sq cm, application of skin substitute graft to trunk, arms, legs, total wound surface area greater than or equal to 100 sq cm	8.9 (1.3)	9.9 (0.9)	−9.68%	0.228448
Muscle, myocutaneous, or fasciocutaneous flap; upper extremity	1.7 (0.3)	1.3 (0.2)	28.33%	0.081850
Muscle, myocutaneous, or fasciocutaneous flap; lower extremity	3.1 (0.3)	3.7 (0.3)	−18.17%	0.020915
Muscle or myocutaneous free flap with microvascular transfer	2.1 (0.3)	2.1 (0.1)	−0.25%	0.963461
Excision, excessive skin and subcutaneous tissue (includes lipectomy); abdomen, infraumbilical panniculectomy	3 (1.3)	6.2 (0.6)	−51.93%	0.001371
Excision, sacral pressure ulcer	1.8 (0.3)	1.5 (0.2)	17.95%	0.176417
Facial nerve paralysis graft	2 (0.5)	1.8 (0.1)	9.79%	0.447072
Limited pharyngectomy, reconstruction of pharyngeal wall closure with flap or flap with microvascular anastomosis, resection of lateral pharyngeal wall or pyriform sinus direct closure	2.3 (0.3)	2.2 (0.4)	3.08%	0.784904
Mammaplasty, augmentation; with prosthetic implant	2.7 (0.3)	4.1 (0.5)	−34.13%	0.003193
Mastopexy	3.1 (1.2)	5.8 (0.5)	−45.95%	0.001746
Reduction mammaplasty	5.7 (2.2)	10.4 (0.7)	−45.59%	0.001252
Prosthetic breast reconstruction	7 (2.1)	9.3 (0.7)	−24.76%	0.037483
Autologus breast reconstruction	1.9 (0.5)	2.9 (0.5)	−34.85%	0.022874
Revision of reconstructed breast	4.2 (2.2)	8.1 (0.7)	−48.44%	0.004118
Free flap procedures	5.5 (0.6)	5.6 (0.6)	−0.52%	0.949261
Pressure ulcer repair	1.8 (0.2)	1.8 (0.2)	0.01%	0.999150
Incision, extensor tendon sheath, wrist (eg, de quervains disease)	4.1 (1.4)	4.9 (0.4)	−15.34%	0.239220
Open treatment of metacarpal fracture, single, includes internal fixation, when performed, each bone	3.7 (0)	4.1 (0.5)	−8.32%	0.285321
Rhinoplasty, primary	2.9 (0.9)	4.8 (0.5)	−41.05%	0.002804
Neuroplasty, major peripheral nerve, arm or leg, open	5.2 (1.2)	5.8 (0.4)	−10.32%	0.285126
Neuroplasty and/or transposition; median nerve at carpal tunnel	21.4 (12)	38.2 (1.1)	−44.08%	0.008050

Table 3 Seasonal mean procedural volumes per HCO and associated standard deviation (SD) for summer 2020 (pandemic) and summer 2018/2019 (pre-pandemic), fall 2020 (pandemic) and fall 2018/2019 (pre-pandemic), & winter 2020 (pandemic) and winter 2018/2019 (pre-pandemic) along with the respective procedure-specific changes (in%) and statistical significance of the changes (denoted by *p*-value).

CPT Codes	JUNE TO AUGUST - 2020 VS 2018/2019				SEPTEMBER TO NOVEMBER - 2020 VS 2018/2019				DECEMBER TO FEBRUARY - 2020/2021 VS 2018/2019			
	Pandemic Mean (SD)	Pre-pandemic Mean (SD)	Percent Change (%)	P-value	Pandemic Mean (SD)	Pre-pandemic Mean (SD)	Percent Change (%)	P-value	Pandemic Mean (SD)	Pre-pandemic Mean (SD)	Percent Change (%)	P-value
Debridement, muscle and/or fascia (includes epidermis, dermis, and subcutaneous tissue, if performed); first 20 sq cm or less	20.3 (2)	22.9 (3.1)	−11.1%	0.24	23.1 (3)	21.7 (2.6)	6.6%	0.486	22.5 (0.9)	21.5 (2)	4.6%	0.448
Debridement, bone (includes epidermis, dermis, subcutaneous tissue, muscle and/or fascia, if performed); first 20 sq cm or less	11.1 (0.6)	11.7 (0.8)	−5%	0.295	12.2 (0.9)	12.1 (0.6)	0.5%	0.912	10.7 (0.8)	11.1 (0.8)	−3.5%	0.522
Excision, benign lesion including margins, except skin tag (unless listed elsewhere), trunk, arms or legs; excised diameter 1.1 to 2.0 cm	17.3 (1.6)	17.8 (1.2)	−3%	0.596	17.4 (1.3)	17.6 (1.4)	−1.6%	0.782	15.2 (1)	17.2 (1.3)	−11.6%	0.056
Excision, malignant lesion including margins, trunk, arms, or legs; excised diameter 1.1 to 2.0 cm, excision, malignant lesion including margins, trunk, arms, or legs; excised diameter 2.1 to 3.0 cm	22.8 (2.1)	22.7 (1.5)	0.3%	0.96	24.9 (3.6)	24 (2.9)	4%	0.669	22.4 (0.8)	24.5 (3.4)	−8.4%	0.351
Adjacent tissue transfer or rearrangement, eyelids, nose, ears and/or lips	18.7 (0.6)	17.7 (1.2)	5.2%	0.243	19.5 (0.8)	18.9 (1.3)	3.3%	0.481	16.6 (1.2)	18.3 (1.7)	−9.5%	0.166
Repair, complex, forehead, cheeks, chin, mouth, neck, axillae, genitalia, hands and/or feet; 1.1 cm to 2.5 cm-7.5cm	38.1 (1.2)	38.2 (1.2)	−0.2%	0.942	36.3 (4.5)	36.5 (3.6)	−0.6%	0.936	27 (1.8)	36.5 (2.3)	−26.0%	0.000
Adjacent tissue transfer or rearrangement, any area; defect 30.1–60.0 cm2	10.5 (1.3)	11.2 (1.3)	−6.1%	0.474	12.3 (0.9)	11.5 (1.1)	6.5%	0.333	12.5 (0.6)	11 (1.3)	13.1%	0.112

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Table 3 (*continued*)

CPT Codes	JUNE TO AUGUST - 2020 VS 2018/2019				SEPTEMBER TO NOVEMBER - 2020 VS 2018/2019				DECEMBER TO FEBRUARY - 2020/2021 VS 2018/2019			
	Pandemic Mean (SD)	Pre-pandemic Mean (SD)	Percent Change (%)	P-value	Pandemic Mean (SD)	Pre-pandemic Mean (SD)	Percent Change (%)	P-value	Pandemic Mean (SD)	Pre-pandemic Mean (SD)	Percent Change (%)	P-value
Split-thickness autograft, trunk, arms, legs; first 100 cm2 or less, or 1% of body area of infants and children	11.1 (0.1)	11.2 (0.8)	−0.9%	0.846	10.8 (1.5)	10.5 (1.1)	2.5%	0.77	10.7 (0.3)	9.8 (0.8)	8.8%	0.140
Full-thickness graft, free, including direct closure of donor site, forehead, cheeks, chin, mouth, neck, axillae, genitalia, hands, and/or feet; 20 cm2 or less	4.7 (0.9)	4.7 (0.6)	0.2%	0.985	5.3 (0.6)	5.1 (0.5)	4.8%	0.527	5.3 (0.1)	4.4 (0.5)	18.5%	0.027
Application of skin substitute graft to trunk, arms, legs, total wound surface area up to 100 sq cm, application of skin substitute graft to trunk, arms, legs, total wound surface area greater than or equal to 100 sq cm	9.1 (0.3)	9.7 (1.1)	−6.8%	0.359	11 (0.5)	10 (1.2)	10.2%	0.201	9 (0.6)	9.4 (0.6)	−4.5%	0.365
Muscle, myocutaneous, or fasciocutaneous flap; upper extremity	1.5 (0.2)	1.5 (0.2)	0.7%	0.924	1.9 (0.5)	1.7 (0.4)	11.8%	0.554	1.8 (0.4)	1.3 (0.2)	33.5%	0.049
Muscle, myocutaneous, or fasciocutaneous flap; lower extremity	3.3 (0.1)	3.4 (0.2)	−2.7%	0.415	3.3 (0.1)	3.3 (0.2)	−1.8%	0.617	3.9 (0.2)	3.2 (0.5)	20.1%	0.075
Muscle or myocutaneous free flap with microvascular transfer	2.2 (0.2)	2.3 (0.2)	−2.8%	0.709	2.1 (0.2)	2.3 (0.3)	−6.6%	0.41	2.5 (0.7)	2.1 (0.5)	17.2%	0.374
Excision, excessive skin and subcutaneous tissue (includes lipectomy); abdomen, infraumbilical panniculectomy	5.4 (0.6)	5.3 (0.4)	0.6%	0.932	5.3 (0.8)	5.2 (0.5)	1.4v%	0.872	5.1 (0.8)	5.6 (0.4)	−9.9%	0.188
Excision, sacral pressure ulcer	1.6 (0.5)	1.4 (0.4)	10.5%	0.598	2.6 (2.1)	2 (1.5)	28.5%	0.649	2.1 (1)	1.6 (0.2)	33.6%	0.242
Facial nerve paralysis graft	1.7 (0.4)	1.7 (0.4)	−0.3%	0.983	1.7 (0.2)	1.9 (0.4)	−11.9%	0.441	2.3 (0.5)	1.9 (0.3)	21.4%	0.148

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Table 3 (*continued*)

CPT Codes	JUNE TO AUGUST - 2020 VS 2018/2019				SEPTEMBER TO NOVEMBER - 2020 VS 2018/2019				DECEMBER TO FEBRUARY - 2020/2021 VS 2018/2019			
	Pandemic Mean (SD)	Pre-pandemic Mean (SD)	Percent Change (%)	P-value	Pandemic Mean (SD)	Pre-pandemic Mean (SD)	Percent Change (%)	P-value	Pandemic Mean (SD)	Pre-pandemic Mean (SD)	Percent Change (%)	P-value
Limited pharyngectomy, reconstruction of pharyngeal wall closure with flap or flap with microvascular anastomosis, resection of lateral pharyngeal wall or pyriform sinus direct closure	2.4 (0.3)	2.3 (0.3)	4.7%	0.628	2.1 (0.2)	2.3 (0.2)	−5%	0.418	2.2 (0.3)	2.1 (0.1)	4.1%	0.558
Mammaplasty, augmentation; with prosthetic implant	4.6 (0.5)	4 (0.7)	14.6%	0.241	3.5 (0.7)	3.4 (0.6)	3.9%	0.782	3.4 (0.4)	3.5 (0.6)	−3.0%	0.791
Mastopexy	5.6 (0.5)	5.6 (0.4)	−1%	0.855	5.9 (0.6)	5.7 (0.7)	4.3%	0.633	4.4 (0.3)	5.3 (0.5)	−16.9%	0.037
Reduction mammaplasty	10.9 (0.6)	11 (0.4)	−0.2%	0.943	10.6 (1.1)	10.4 (0.9)	2.3%	0.738	11.3 (0.8)	10.2 (1.5)	10.4%	0.287
Prosthetic breast reconstruction	9.3 (0.4)	9.6 (0.6)	−3%	0.507	10.1 (0.9)	9.9 (1)	2.5%	0.73	10.7 (0.5)	9.5 (0.8)	12.5%	0.064
Autologus breast reconstruction	2.7 (0.1)	2.9 (0.3)	−6.4%	0.321	2.9 (0.1)	2.9 (0.3)	−2%	0.746	2.6 (0.3)	2.8 (0.4)	−6.7%	0.509
Revision of reconstructed breast	7.6 (0.5)	7.9 (0.6)	−4.4%	0.447	9.8 (0.5)	9.6 (1)	2%	0.771	7 (2.4)	8.8 (2.4)	−21.0%	0.314
Free flap procedures	5.8 (0.5)	5.9 (0.5)	−2.1%	0.722	5.5 (0.7)	5.5 (0.5)	0.3%	0.969	6.6 (0.8)	5.3 (0.6)	24.1%	0.026
Pressure ulcer repair	1.9 (0.5)	1.7 (0.4)	13.9%	0.497	1.6 (0.3)	1.5 (0.2)	6%	0.613	1.6 (0.1)	1.6 (0.2)	2.0%	0.816
Incision, extensor tendon sheath, wrist (eg, de quervains disease)	5 (0.3)	5.1 (0.3)	−3.6%	0.458	5.4 (0.7)	5.1 (0.7)	5.6%	0.582	5 (0.7)	5.2 (0.3)	−2.6%	0.679
Open treatment of metacarpal fracture, single, includes internal fixation, when performed, each bone	4.3 (0.3)	4.5 (0.3)	−3.7%	0.432	4.7 (0.7)	4.7 (0.5)	1%	0.914	4.1 (0.6)	4.1 (0.3)	−0.5%	0.941
Rhinoplasty, primary	5.3 (0.2)	5.5 (0.6)	−4.7%	0.514	4.8 (0.2)	4.6 (0.5)	3.1%	0.682	6 (1.1)	4.9 (0.9)	24.4%	0.121
Neuroplasty, major peripheral nerve, arm or leg, open	5.8 (0.4)	6.1 (0.5)	−5.1%	0.359	5.9 (0.6)	5.5 (0.5)	6.5%	0.382	5.9 (0.8)	5.9 (0.5)	0.2%	0.981
Neuroplasty and/or transposition; median nerve at carpal tunnel	36.6 (0.6)	36.6 (0.9)	−0.1%	0.974	38.9 (5.1)	37.5 (4)	3.6%	0.669	37 (3.5)	39.1 (2)	−5.2%	0.296

Table 4 Seasonal mean procedural volumes per HCO and associated standard deviation (SD) for spring 2021 (pandemic) and spring 2018/2019 (pre-pandemic) along with the change (in%) and statistical significance of the change (denoted by *p*-value).

CPT CODES	MARCH TO MAY- 2021 VS 2018/2019 SEASONAL MEAN PROCEDURAL VOLUME PER HCO			
	Pandemic Mean (SD)	Pre-pandemic Mean (SD)	Percent Change (%)	P-value
Debridement, muscle and/or fascia (includes epidermis, dermis, and subcutaneous tissue, if performed); first 20 sq cm or less	23.1 (1.5)	21.2 (3)	9.19%	0.328955
Debridement, bone (includes epidermis, dermis, subcutaneous tissue, muscle and/or fascia, if performed); first 20 sq cm or less	11.8 (0.5)	11.5 (1.7)	2.76%	0.771666
Excision, benign lesion including margins, except skin tag (unless listed elsewhere), trunk, arms or legs; excised diameter 1.1 to 2.0 cm	18.2 (1.9)	18.4 (0.4)	−1.26%	0.767534
Excision, malignant lesion including margins, trunk, arms, or legs; excised diameter 1.1 to 2.0 cm, excision, malignant lesion including margins, trunk, arms, or legs; excised diameter 2.1 to 3.0 cm	25.1 (1.2)	22.5 (1.5)	11.46%	0.036480
Adjacent tissue transfer or rearrangement, eyelids, nose, ears and/or lips	20 (1.9)	17.7 (0.9)	12.81%	0.042132
Repair, complex, forehead, cheeks, chin, mouth, neck, axillae, genitalia, hands and/or feet; 1.1 cm to 2.5 cm-7.5cm	33.9 (2.6)	37.3 (2)	−9.16%	0.061549
Adjacent tissue transfer or rearrangement, any area; defect 30.1–60.0 cm2	13.9 (0.6)	11.1 (1.3)	25.73%	0.011204
Split-thickness autograft, trunk, arms, legs; first 100 cm2 or less, or 1% of body area of infants and children	13.3 (0.1)	11 (0.9)	20.10%	0.005093
Full-thickness graft, free, including direct closure of donor site, forehead, cheeks, chin, mouth, neck, axillae, genitalia, hands, and/or feet; 20 cm2 or less	6.3 (0.9)	4.4 (0.4)	41.01%	0.003197
Application of skin substitute graft to trunk, arms, legs, total wound surface area up to 100 sq cm, application of skin substitute graft to trunk, arms, legs, total wound surface area greater than or equal to 100 sq cm	12.3 (0.6)	9.9 (0.9)	24.68%	0.003493
Muscle, myocutaneous, or fasciocutaneous flap; upper extremity	1.4 (0.3)	1.3 (0.2)	8.36%	0.577432
Muscle, myocutaneous, or fasciocutaneous flap; lower extremity	3.7 (0.1)	3.7 (0.3)	−0.61%	0.913985
Muscle or myocutaneous free flap with microvascular transfer	2.8 (0.3)	2.1 (0.1)	34.36%	0.001079
Excision, excessive skin and subcutaneous tissue (includes lipectomy); abdomen, infraumbilical panniculectomy	6.1 (0.3)	6.2 (0.6)	−2.46%	0.703413
Excision, sacral pressure ulcer	2.2 (0.6)	1.5 (0.2)	43.99%	0.029862
Facial nerve paralysis graft	2.1 (0)	1.8 (0.1)	17.75%	0.006303
Limited pharyngectomy, reconstruction of pharyngeal wall closure with flap or flap with microvascular anastomosis, resection of lateral pharyngeal wall or pyriform sinus direct closure	2.7 (0.4)	2.2 (0.4)	22.73%	0.098526
Mammaplasty, augmentation; with prosthetic implant	4.3 (0.8)	4.1 (0.5)	5.35%	0.617271
Mastopexy	5.3 (0.5)	5.8 (0.5)	−8.80%	0.196518
Reduction mammaplasty	12.3 (0.9)	10.4 (0.7)	18.03%	0.008987
Prosthetic breast reconstruction	12.5 (0.1)	9.3 (0.7)	35.39%	0.000122
Autologus breast reconstruction	3.5 (0.8)	2.9 (0.5)	19.93%	0.209513
Revision of reconstructed breast	6.7 (0.7)	8.1 (0.7)	−17.28%	0.022307
Free flap procedures	7.3 (1.1)	5.6 (0.6)	30.30%	0.021516
Pressure ulcer repair	2.2 (0.3)	1.8 (0.2)	19.20%	0.067430
Incision, extensor tendon sheath, wrist (eg, de quervains disease)	5.4 (0.6)	4.9 (0.4)	11.16%	0.166190
Open treatment of metacarpal fracture, single, includes internal fixation, when performed, each bone	4.2 (0.2)	4.1 (0.5)	3.85%	0.622362
Rhinoplasty, primary	7.1 (0.4)	4.8 (0.5)	45.64%	0.000304
Neuroplasty, major peripheral nerve, arm or leg, open	7.4 (1.1)	5.8 (0.4)	28.99%	0.009368
Neuroplasty and/or transposition; median nerve at carpal tunnel	45 (2.7)	38.2 (1.1)	17.74%	0.000834

Table 5 Seasonal mean procedural volumes per HCO and associated standard deviation (SD) over the aggregate March 2020 – May 2021 period (pandemic) and aggregate March 2018 – February 2020 (pre-pandemic) period along with the change (in%) and statistical significance of the change (denoted by *p*-value).

CPT CODES	PANDEMIC VS PRE-PANDEMIC SEASONAL MEAN PROCEDURAL VOLUME PER HCO			
	Pandemic Mean (SD)	Pre-pandemic Mean (SD)	Percent Change (%)	P-value
Debridement, muscle and/or fascia (includes epidermis, dermis, and subcutaneous tissue, if performed); first 20 sq cm or less	23.28 (1.6)	21.80 (2.6)	6.81%	0.05478
Debridement, bone (includes epidermis, dermis, subcutaneous tissue, muscle and/or fascia, if performed); first 20 sq cm or less	11.02 (1.0)	11.60 (1.1)	−4.93%	0.10593
Excision, benign lesion including margins, except skin tag (unless listed elsewhere), trunk, arms or legs; excised diameter 1.1 to 2.0 cm	14.82 (3.7)	17.76 (1.2)	−16.56%	0.00082
Excision, malignant lesion including margins, trunk, arms, or legs; excised diameter 1.1 to 2.0 cm, excision, malignant lesion including margins, trunk, arms, or legs; excised diameter 2.1 to 3.0 cm	22.38 (4.7)	23.42 (2.4)	−4.45%	0.36804
Adjacent tissue transfer or rearrangement, eyelids, nose, ears and/or lips	16.62 (3.3)	18.16 (1.3)	−8.47%	0.04801
Repair, complex, forehead, cheeks, chin, mouth, neck, axillae, genitalia, hands and/or feet; 1.1 cm to 2.5 cm-7.5cm	28.33 (4.9)	37.14 (2.4)	−23.71%	5.9803E-09
Adjacent tissue transfer or rearrangement, any area; defect 30.1–60.0 cm2	12.05 (2.1)	11.21 (1.2)	7.58%	0.11262
Split-thickness autograft, trunk, arms, legs; first 100 cm2 or less, or 1% of body area of infants and children	11.09 (1.6)	10.65 (1.0)	4.15%	0.30168
Full-thickness graft, free, including direct closure of donor site, forehead, cheeks, chin, mouth, neck, axillae, genitalia, hands, and/or feet; 20 cm2 or less	5.22 (1.0)	4.67 (0.5)	11.76%	0.03013
Application of skin substitute graft to trunk, arms, legs, total wound surface area up to 100 sq cm, application of skin substitute graft to trunk, arms, legs, total wound surface area greater than or equal to 100 sq cm	9.99 (1.5)	9.77 (0.9)	2.17%	0.58763
Muscle, myocutaneous, or fasciocutaneous flap; upper extremity	1.64 (0.3)	1.46 (0.3)	12.31%	0.07588
Muscle, myocutaneous, or fasciocutaneous flap; lower extremity	3.48 (0.4)	3.43 (0.4)	1.41%	0.70770
Muscle or myocutaneous free flap with microvascular transfer	2.57 (0.4)	2.20 (0.3)	16.79%	0.00305
Excision, excessive skin and subcutaneous tissue (includes lipectomy); abdomen, infraumbilical panniculectomy	4.89 (1.2)	5.59 (0.6)	−12.44%	0.02408

(*continued on next page*)

Table 5 (*continued*)

CPT CODES	PANDEMIC VS PRE-PANDEMIC SEASONAL MEAN PROCEDURAL VOLUME PER HCO			
	Pandemic Mean (SD)	Pre-pandemic Mean (SD)	Percent Change (%)	P-value
Excision, sacral pressure ulcer	1.97 (0.6)	1.64 (0.8)	20.50%	0.15527
Facial nerve paralysis graft	1.98 (0.4)	1.84 (0.3)	7.66%	0.25713
Limited pharyngectomy, reconstruction of pharyngeal wall closure with flap or flap with microvascular anastomosis, resection of lateral pharyngeal wall or pyriform sinus direct closure	2.30 (0.4)	2.22 (0.3)	3.69%	0.45566
Mammaplasty, augmentation; with prosthetic implant	3.43 (0.7)	3.77 (0.7)	−8.94%	0.13090
Mastopexy	4.55 (1.1)	5.59 (0.6)	−18.55%	0.00028
Reduction mammaplasty	10.04 (2.6)	10.49 (0.9)	−4.29%	0.43715
Prosthetic breast reconstruction	9.91 (2.0)	9.55 (0.8)	3.76%	0.43957
Autologus breast reconstruction	2.73 (0.7)	2.88 (0.4)	−5.41%	0.36385
Revision of reconstructed breast	6.76 (2.0)	8.62 (1.5)	−21.56%	0.00183
Free flap procedures	6.60 (0.8)	5.57 (0.6)	18.39%	5.304E-05
Pressure ulcer repair	1.79 (0.3)	1.64 (0.3)	8.66%	0.13406
Incision, extensor tendon sheath, wrist (eg, de quervains disease)	4.91 (0.8)	5.08 (0.5)	−3.31%	0.42648
Open treatment of metacarpal fracture, single, includes internal fixation, when performed, each bone	4.10 (0.5)	4.32 (0.5)	−5.13%	0.17642
Rhinoplasty, primary	5.43 (1.5)	4.97 (0.7)	9.27%	0.21083
Neuroplasty, major peripheral nerve, arm or leg, open	6.38 (1.1)	5.82 (0.5)	9.62%	0.03605
Neuroplasty and/or transposition; median nerve at carpal tunnel	35.53 (9.4)	37.87 (2.4)	−6.16%	0.25107

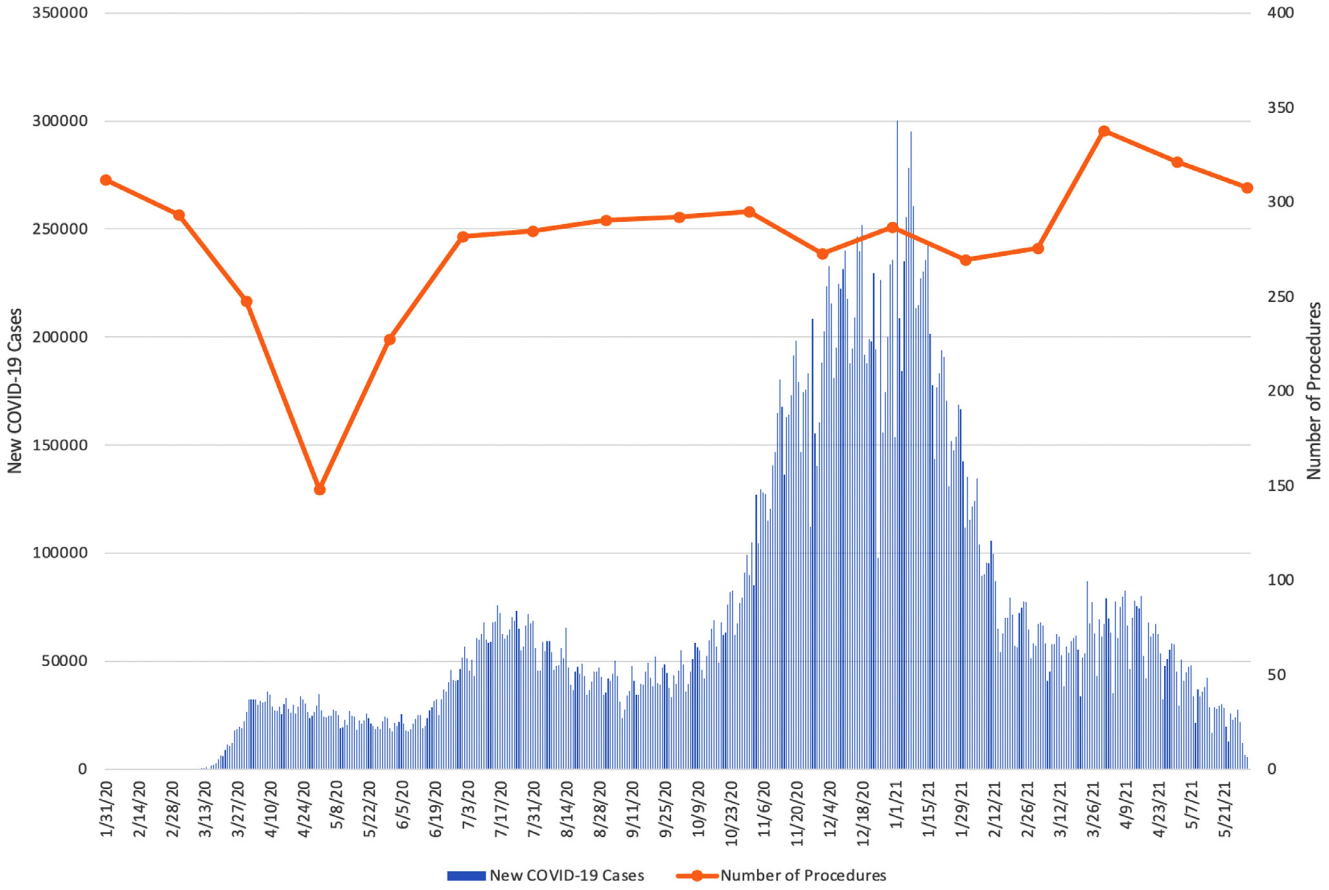

Fig. 1 This Figure illustrates the monthly procedural volume per HCO of all included procedures overlayed atop a bar graph tracking COVID-19 cases from January 2020 – May 2021.

and reconstructive surgical care during the COVID-19 pandemic.

Following the initial procedural decline in spring 2020, this analysis demonstrates a gradual escalation in the number of cases performed across the country culminating in a compensatory increase in procedural volume compared to pre-pandemic levels witnessed in spring 2021 to address months of accrued backlogged cases. Furthermore, increases in specific procedural volumes represent the management of backlog-associated financial impact. Besides the obvious decrease in billable relative value units, elective surgery backlogs have been associated with an extensive economic impact in current literature [25-30].

Various interesting trends can be gleaned from the current analysis. The significant decrease in the mean revision of reconstructed breast procedures performed per HCO in spring 2021 demonstrates an immediate effect of changes in seasonal operative volume per HCO. All breast reconstruction operations decreased in seasonal mean frequency per HCO in spring 2020. The decrease in breast reconstructions performed during this time yields fewer possible cases for subsequent revision of reconstruction. While other revision procedures were not included in our investigation, this analysis suggests an analogous trend for other revisional operations.

When analyzed alongside new U.S. COVID-19 cases, our results suggest an inverse relationship between new U.S. COVID-19 cases and plastic and reconstructive surgery procedure volumes. Initial spring 2020 vol decreases likely stem from the first rise in COVID-19 cases. Comparison of USA COVID-19 cases over time versus monthly total procedural volumes confirms this supposition (Fig. 1). Winter 2020/2021 peak caseload, however, coincided with an incremental increase in total plastic and reconstructive procedures. This suggests a combination of factors that influenced procedural volume including, though not limited to local, state, and federal regulations, weather, social and political climate, and general economic conditions.

Overall, our findings imply that as we experience future waves of new cases alongside novel variant strains of COVID-19 (i.e., delta and lambda variants), healthcare organizations will need to anticipate and prepare for seasonal variation in procedural volume. These changes will likely follow procedure-specific trends that track variation in new cases. This could change procedural and peri- and post-operative care protocols as well. As the pandemic continues, this could represent opportunities for the utilization of telemedicine and other remote care options.

Our utilization of the TriNetX dataset posed several limitations to our study. By nature of the de-identified EHR, patient information regarding case complexity, emergence, and severity were not available. Our data also could not be stratified geographically to assess mean procedural volume per HCO more accurately. Given the characteristically large

HCOs reporting EHR data, TriNetX data may also have unadjusted biases against smaller hospitals or individual practices. Finally, our data may have been limited by confounding variables. For example, stay-at-home mandates may have diminished traumatic injuries requiring plastic and reconstructive repair. Given the limited duration and inconsistency of mandate enforcement, this effect is likely limited to earlier in the course of the COVID-19 pandemic when mandates were more restrictive.

We suggest that future investigations should focus on the economic and healthcare impacts of accumulated demand and backlog for plastic and reconstructive care. Increases in spring 2021 procedural volume could potentially be associated with deteriorations in surgical outcomes and patient quality and satisfaction measures. Investigation of these specific protocols reveals improvements in safety and efficiency necessary for the delivery of plastic and reconstructive care in the era of COVID-19. These analyses may serve as guidelines for the plastic and reconstructive surgery community in the event of subsequent pandemics of this magnitude. Furthermore, by understanding backlogs created by reduced surgical volume, astute clinicians can adjust their practice to address the increased demand for various procedures.

Conclusion

Summing up, to our knowledge, the present study represents the first study of its kind to define the effects of COVID-19 on plastic and reconstructive operational volume on a national level in the USA. We found statistically significant decreases in common plastic and reconstructive surgeries from March to May 2020 compared to pre-pandemic levels and a subsequent significant increase in volume from March to May 2021 compared to pre-pandemic levels.

Declaration of Competing Interest

The authors have no conflicts of interest.

Ethical approval

Not required.

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