

IV Fluid Administration in Orthognathic Patients Before and After Hurricane Helene

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Background and Study Overview

In September 2024, Hurricane Helene made landfall as a Category 4 storm, devastating parts of the Southeastern United States and causing catastrophic flooding in western North Carolina. This flooding led to the closure of Baxter International's North Cove facility in Marion, a critical supplier responsible for approximately 60% of the U.S. intravenous (IV) fluid market. As a result, hospitals nationwide faced an acute IV fluid shortage and implemented conservation strategies, including administering oral hydration solutions (e.g., Gatorade) to patients who could tolerate them, using alternative hydration methods, and closely conserving and monitoring IV fluid usage.

To assess the impact of Hurricane Helene on post-operative outcomes across different surgical procedures, a retrospective cohort study was done comparing patients who underwent orthognathic surgery in the 12 months prior to the shortage (pre-Hurricane Helene group: October 3, 2023 – October 3, 2024; $n = 279$) with those who underwent surgery in the four months following the hurricane (post-Hurricane Helene group: October 4, 2024 – February 14, 2025; $n = 104$).

Methods

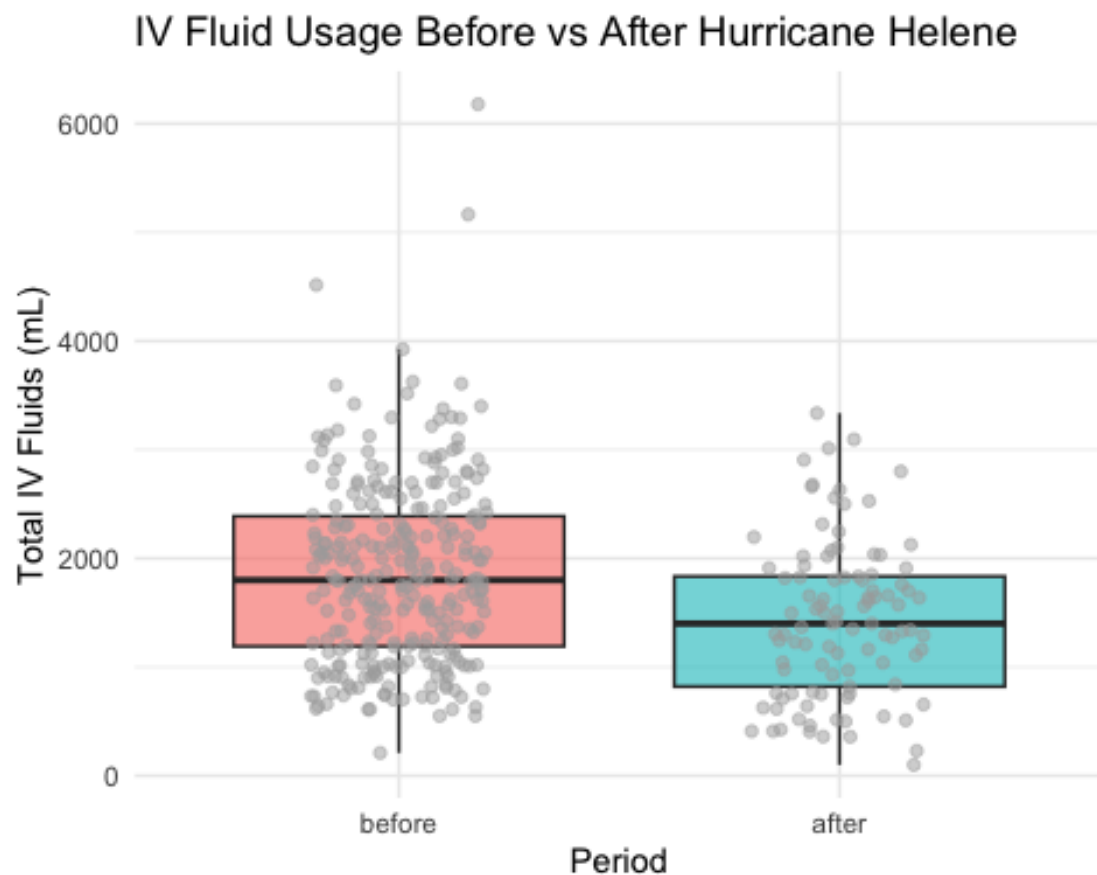
To assess the impact of Hurricane Helene on post-operative outcomes across different surgical procedures, we conducted a series of statistical and visual analyses using data from patients treated before and after the event. We first categorized the data by procedure and period (pre- vs. post-hurricane) and generated boxplots to visualize the distributions of key clinical outcomes, including PO intake on POD1, length of hospital stay, post-operative IV fluids, total IV fluid use, surgical time, and estimated blood loss.

We also performed t-tests within each procedure group to evaluate whether observed differences were statistically significant. Where applicable, variables were analyzed in their raw units without transformation, and we accounted for missing data by filtering incomplete observations prior to

testing. This multi-faceted approach allowed us to highlight potential procedural or systemic shifts in perioperative care associated with the hurricane. A normal distribution was assumed across all data when running t-tests.

Statistical Analysis

Comparing the total IV fluid usage (total_fluid) among patients who underwent surgery before and after Hurricane Helene:



Based on the box plot, we observe that the median fluid usage is lower in the after group compared to the before group. The spread (IQR) is also smaller in the after group, suggesting more standardized fluid use, while the before group shows several extreme high outliers.

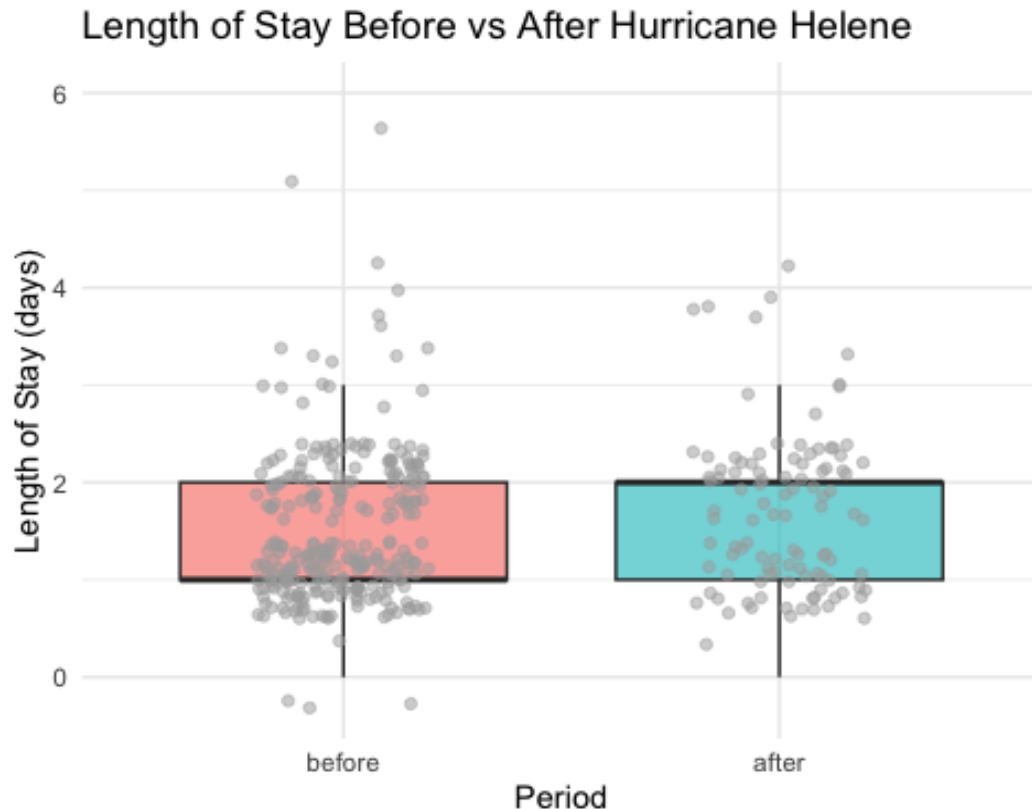
```
# Statistical test
t.test(total_fluid ~ period, data = combined, var.equal = TRUE)

##
## Two Sample t-test
```

```
##
## data: total_fluid by period
## t = 4.6204, df = 378, p-value = 5.261e-06
## alternative hypothesis: true difference in means between group before and
## group after is not equal to 0
## 95 percent confidence interval:
## 251.4273 623.9546
## sample estimates:
## mean in group before mean in group after
## 1867.266 1429.576
```

The two-sample t-test is used to compare the means of two groups. We have made the assumption that the data follows a normal distribution. From the t-test, the mean total fluid usage significantly decreased from approximately 1,867 mL to 1,429 mL after Hurricane Helene. This difference is statistically significant ($p < 0.001$), indicating it is highly unlikely that the change occurred by chance. The 95% confidence interval (–610 to –265 mL) suggests a true average reduction of 265–610 mL per patient.

Comparing the hospital length of stay (los) in days between patients treated before by Hurricane Helene and after.



```

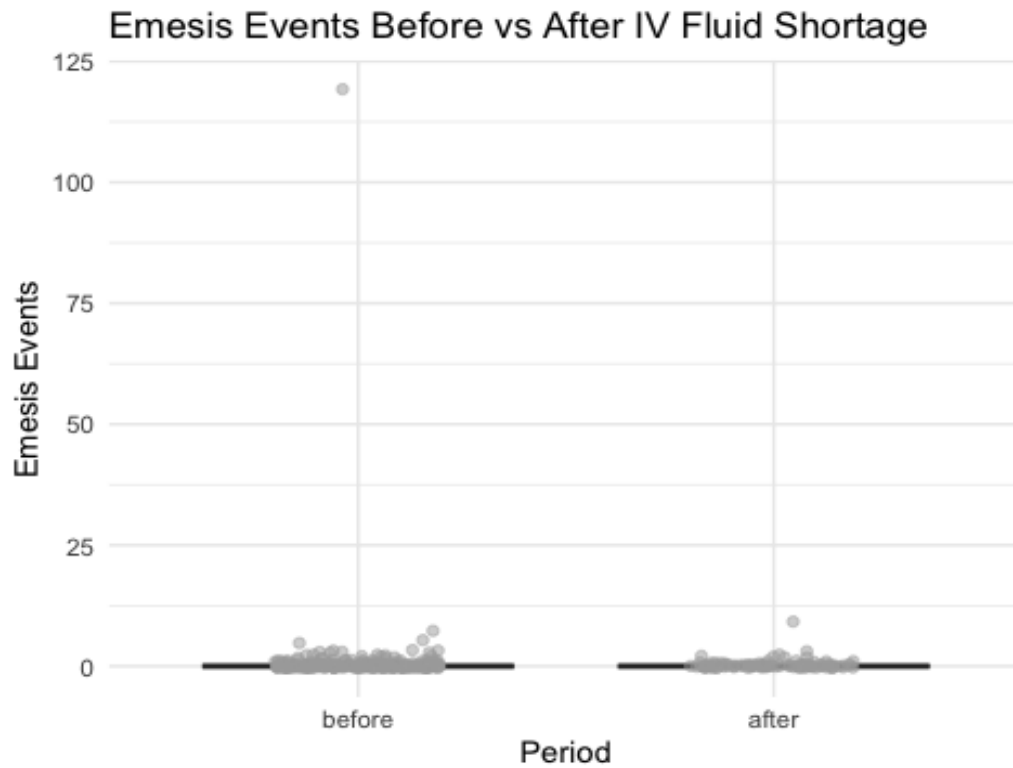
t.test(los ~ period, data = combined, var.equal = TRUE)

##
## Two Sample t-test
##
## data: los by period
## t = -2.032, df = 381, p-value = 0.04285
## alternative hypothesis: true difference in means between group before and
## group after is not equal to 0
## 95 percent confidence interval:
## -0.351131059 -0.005775475
## sample estimates:
## mean in group before mean in group after
## 1.494624 1.673077

```

The box plot shows that the median LOS is slightly higher in the “after” group, with similar overall spread across both groups. There are more high outliers in the “before” group (up to 6 days), but both distributions are largely centered around 1–2 days. Welch’s two-sample t-test supports this, showing a significant increase in mean LOS from 1.49 to 1.67 days ($p = 0.04285$), reflecting an average increase of about 4 hours. Although this difference is clinically small, it may reflect downstream effects of the fluid conservation measures implemented during the shortage period.

Comparing the number of emesis events between patients treated before by Hurricane Helene and after.

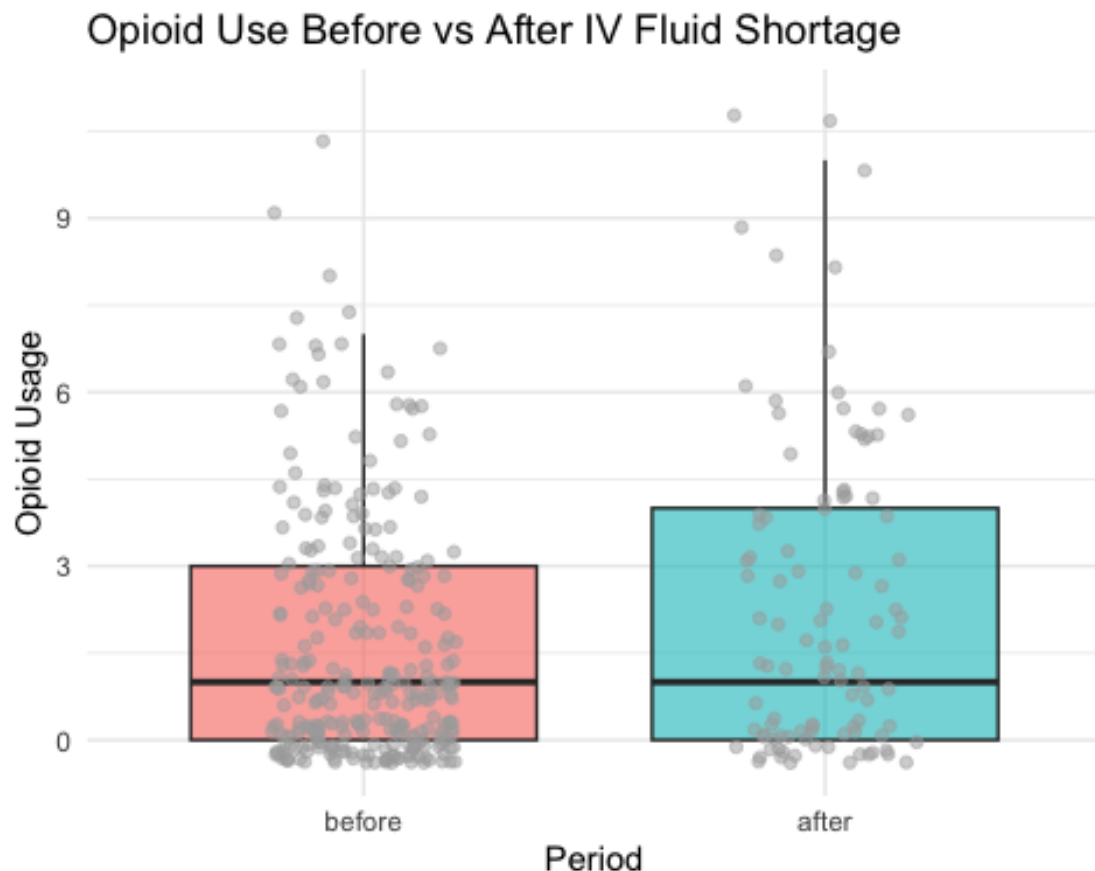


```
t.test(emesis ~ period, data = combined, var.equal = TRUE)

##
## Two Sample t-test
##
## data: emesis by period
## t = 0.63547, df = 380, p-value = 0.5255
## alternative hypothesis: true difference in means between group before and
group after is not equal to 0
## 95 percent confidence interval:
## -0.940025 1.8377612
## sample estimates:
## mean in group before mean in group after
## 0.7661871 0.3173077
```

Examining emesis events before and after the IV fluid shortage, the box plot shows that both groups have distributions tightly clustered near zero, with most cases reporting no or very few events. There is one extreme high outlier in each group, but overall the spread and median appear similar. Welch's two-sample t-test shows no statistically significant difference between the groups ($p = 0.52$), with mean emesis events decreasing from ~ 0.77 before to ~ 0.32 after the shortage. The 95% confidence interval (-0.94 to 1.84) crosses zero, indicating no clear evidence of a true difference in average emesis rates between the periods.

Comparing the number of times opioids were used between patients treated before by Hurricane Helene and after.



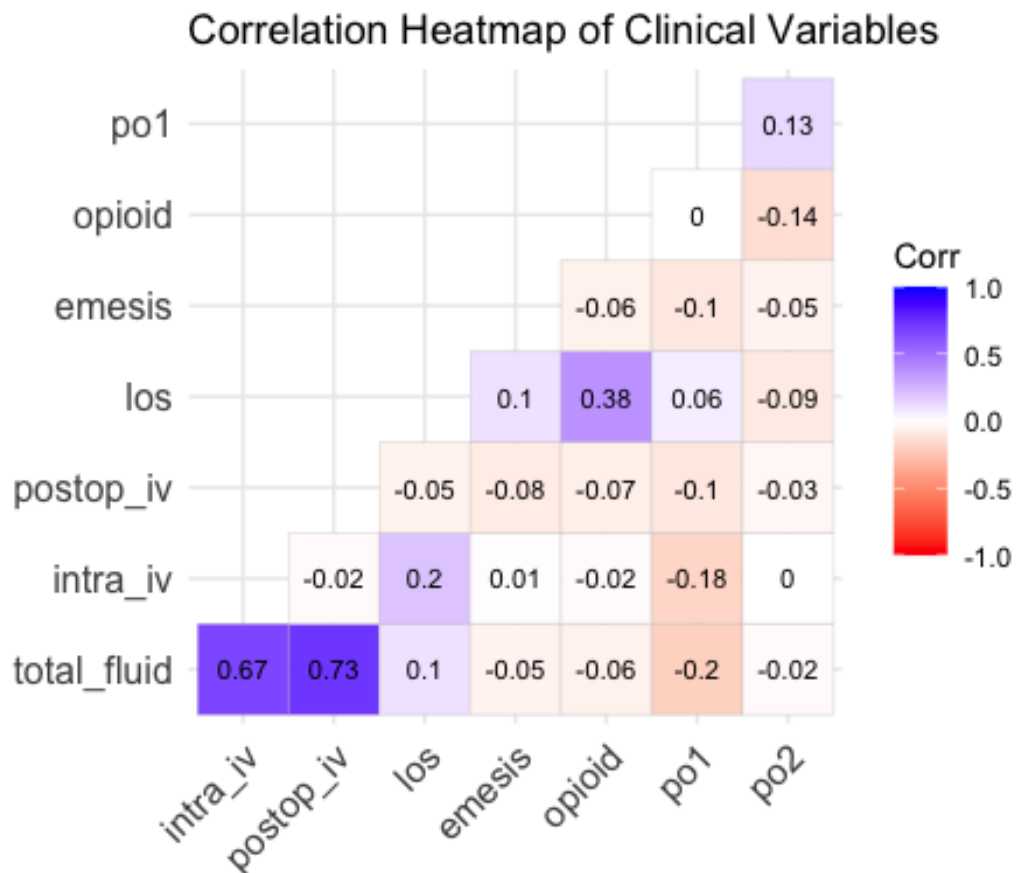
```
t.test(opioid ~ period, data = combined)
```

```
##  
##  Welch Two Sample t-test  
##  
## data:  opioid by period
```

```
## t = -2.7692, df = 145.9, p-value = 0.00635
## alternative hypothesis: true difference in means between group before and
group after is not equal to 0
## 95 percent confidence interval:
## -1.386141 -0.231586
## sample estimates:
## mean in group before mean in group after
## 1.550360 2.359223
```

Looking at opioid use before and after the IV fluid shortage, the box plot shows a noticeable increase in both the median and spread in the “after” group compared to the “before” group. While both groups have some high outliers, the “after” group shows higher overall usage and variability. This visual trend is supported by the Welch two-sample t-test ($p = 0.0064$), indicating a statistically significant increase in mean opioid use from ~ 1.55 to ~ 2.36 units after the shortage. The 95% confidence interval (-1.39 to -0.23) suggests a true average increase of approximately 0.23 – 1.39 units per patient.

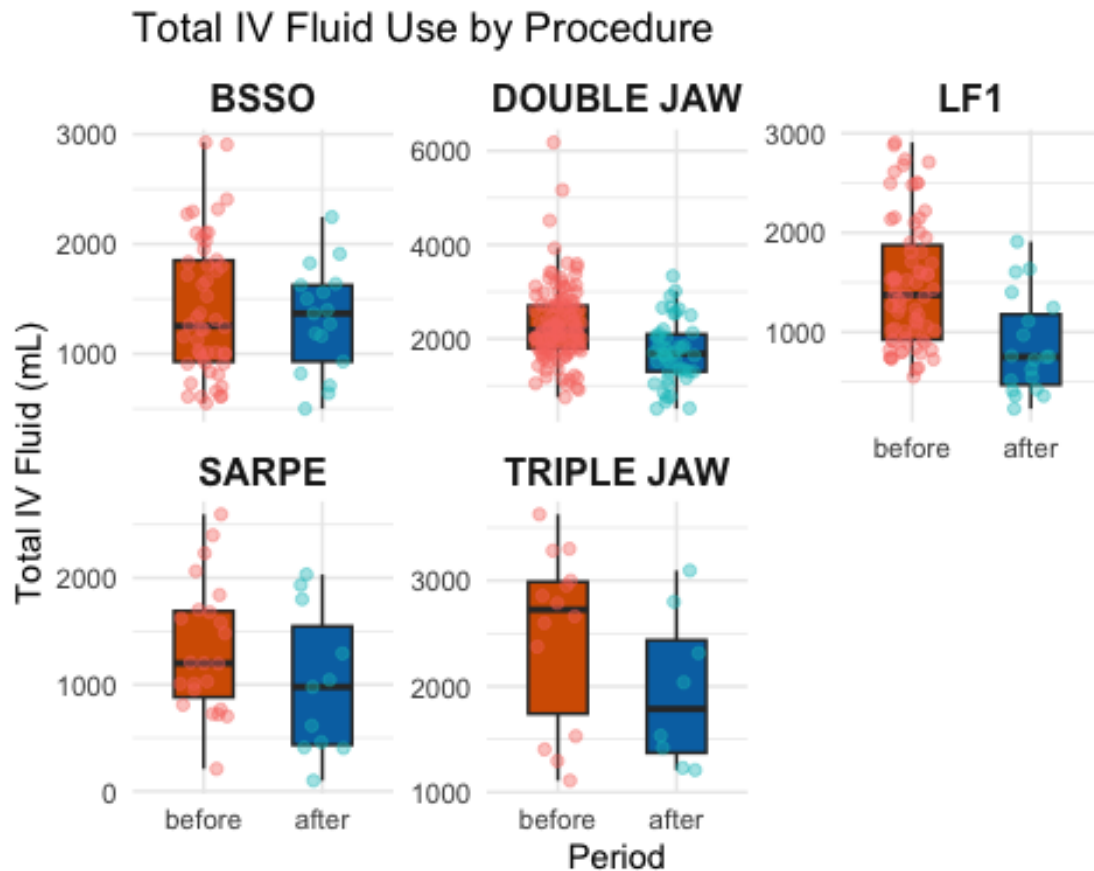
Correlation Analysis between Clinical Variables



Based on the correlation heatmap, we can highlight several key points:

- **Total IV fluid** is strongly correlated with both intraoperative IV fluid ($r = 0.67$) and postoperative IV fluid ($r = 0.73$).
- **Length of stay (LOS)** shows a moderate correlation with emesis events ($r = 0.38$) and a weak correlation with total fluid and postoperative IV fluid ($r \approx 0.1$).
- **Opioid use** has a weak negative correlation with intraoperative IV fluid ($r = -0.18$) and no meaningful correlation with LOS, emesis, or oral intake.
- **Oral intake (po1, po2)** shows slight negative correlations with total fluid and opioid use ($r \approx -0.2$ to -0.14) and is largely uncorrelated with most other variables.

Analysis based on procedure



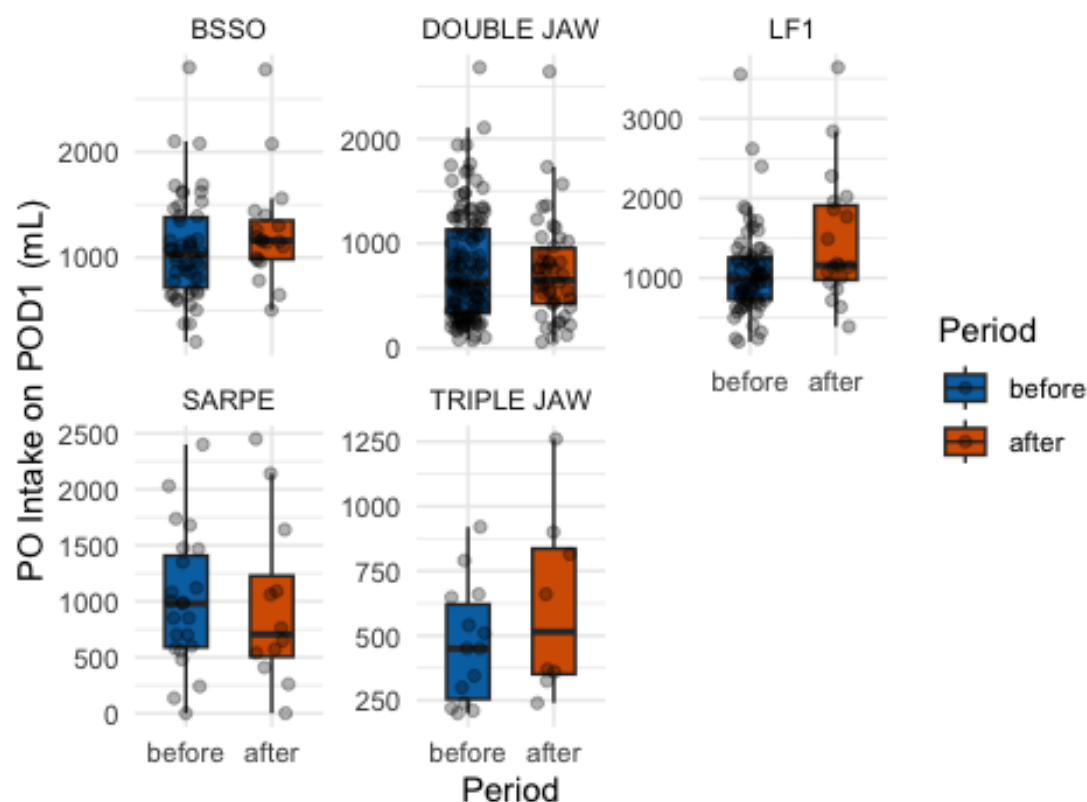
The boxplots show total IV fluid use by procedure before and after Hurricane Helene. Across most of the procedures, the median total IV fluid use decreased in the “after” group compared to the “before” group, with a noticeably narrower spread for some procedures like SARPE and Triple Jaw. Despite some overlap in distributions, the overall pattern suggests reduced fluid administration post-hurricane, likely reflecting conservation efforts during the shortage period. While individual variability remains (especially in larger procedures like Double Jaw), the visual trend aligns with the measured drop in mean total IV fluid.

The following table shows the results of two-sample t-tests comparing total IV fluid use before and after the IV fluid shortage for each surgical procedure. *ns refers to no significance.

| Procedure | Mean | | t-statistic | p-value | Lower CI | Upper CI | Significance |
|------------|--------|--------|-------------|----------|----------|----------|--------------|
| | Before | After | | | | | |
| DOUBLE JAW | 2304.4 | 1718.5 | 4.35 | 2.33e-05 | 320.2 | 851.6 | *** |
| LF1 | 1479.0 | 859.5 | 3.91 | 1.84e-04 | 304.4 | 934.6 | *** |
| SARPE | 1336.0 | 1006.2 | 1.42 | 0.165 | -143.5 | 803.2 | ns |
| BSSO | 1415.7 | 1311.4 | 0.63 | 0.533 | -227.9 | 436.7 | ns |
| TRIPLE JAW | 2484.6 | 1955.4 | 1.51 | 0.146 | -200.2 | 1258.5 | ns |

In the analysis, statistically significant differences were observed for the DOUBLE JAW and LF1 procedures, both showing large, estimated effects with strong significance ($p < 0.001$). In contrast, the SARPE, BSSO, and TRIPLE JAW procedures did not demonstrate significant differences, with p-values above 0.05. These results suggest that only certain surgical procedures showed measurable changes under the conditions assessed, while others remained stable.

Post-Operative PO Intake by Procedure

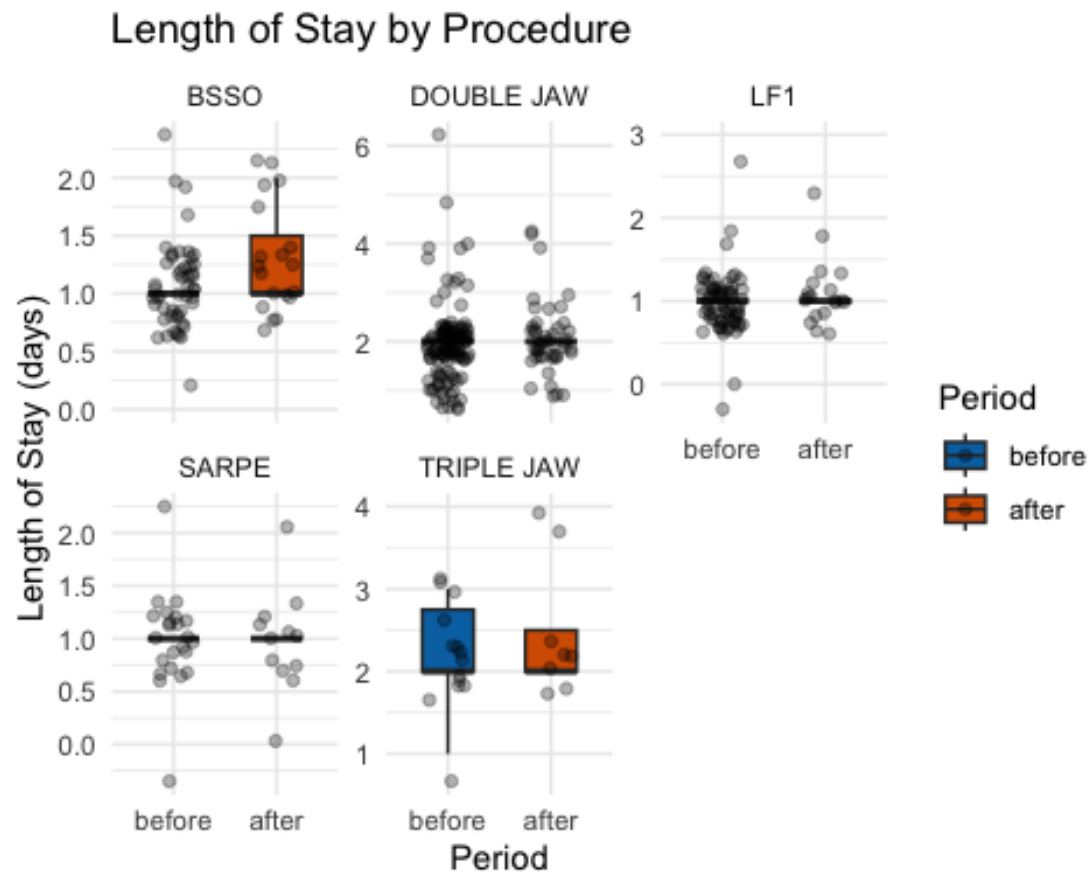


The boxplots show post-operative PO intake by procedure before and after Hurricane Helene. Across most of the procedures, the median post-operative PO intake in the “after” group and the “before” group, are approximately in the same range with a noticeable decrease in the “after” group for SARPE.

The following table shows the results of two-sample t-tests comparing post-operative PO intake before and after the IV fluid shortage for each surgical procedure. *ns refers to no significance.

| Procedure | Mean | | t-statistic | p-value | Lower CI | Upper CI | Significance |
|------------|--------|--------|-------------|---------|----------|----------|--------------|
| | Before | After | | | | | |
| DOUBLE JAW | 765.4 | 732.0 | 0.38 | 0.705 | -140.4 | 207.3 | ns |
| LF1 | 1067.9 | 1479.6 | -2.61 | 0.0107 | -725.5 | -98.0 | * |
| SARPE | 1000.1 | 963.9 | 0.15 | 0.878 | -439.9 | 512.2 | ns |
| BSSO | 1075.5 | 1240.3 | -1.23 | 0.221 | -431.2 | 101.6 | ns |
| TRIPLE JAW | 463.1 | 616.2 | -1.23 | 0.231 | -412.1 | 105.7 | ns |

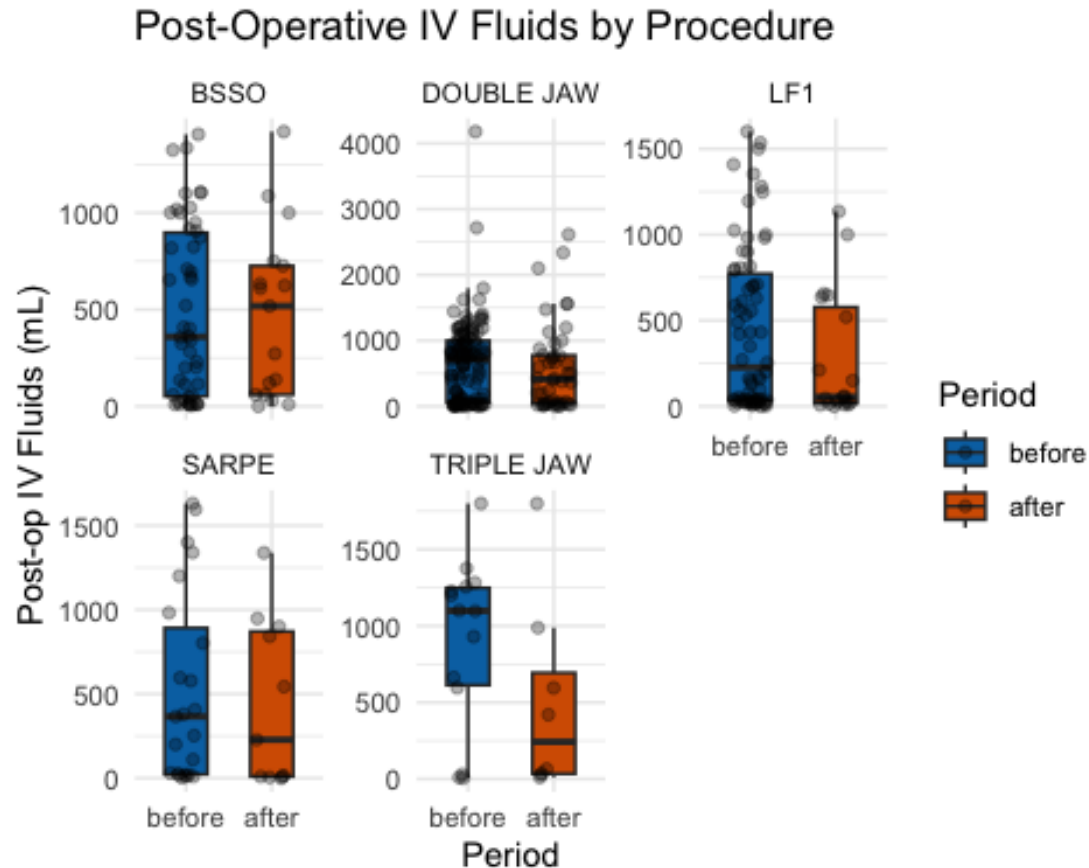
In the analysis, only the LF1 procedure showed a statistically significant difference between the before and after periods ($p = 0.0107$), indicating a meaningful change. The DOUBLE JAW, SARPE, BSSO, and TRIPLE JAW procedures showed no significant differences, suggesting stability across these time points.



The following table shows the results of two-sample t-tests comparing length of stay in hospital before and after the IV fluid shortage for each surgical procedure.

| Procedure | Mean | | t-statistic | p-value | Lower CI | Upper CI | Significance |
|------------|--------|-------|-------------|---------|----------|----------|--------------|
| | Before | After | | | | | |
| DOUBLE JAW | 2.0 | 2.1 | -1.19 | 0.237 | -0.4 | 0.1 | ns |
| LF1 | 1.0 | 1.1 | -0.89 | 0.378 | -0.2 | 0.1 | ns |
| SARPE | 1.0 | 1.0 | 0.00 | 1.00 | -0.3 | 0.3 | ns |
| BSSO | 1.1 | 1.3 | -2.12 | 0.0381 | -0.4 | 0.0 | * |
| TRIPLE JAW | 2.2 | 2.5 | -0.90 | 0.381 | -1.0 | 0.4 | ns |

The two-sample t-tests comparing hospital length of stay before and after the IV fluid shortage showed that only the BSSO procedure had a statistically significant increase ($p = 0.0381$). All other procedures (DOUBLE JAW, LF1, SARPE, and TRIPLE JAW) showed no significant differences, indicating that the shortage did not meaningfully affect their hospital stay durations.

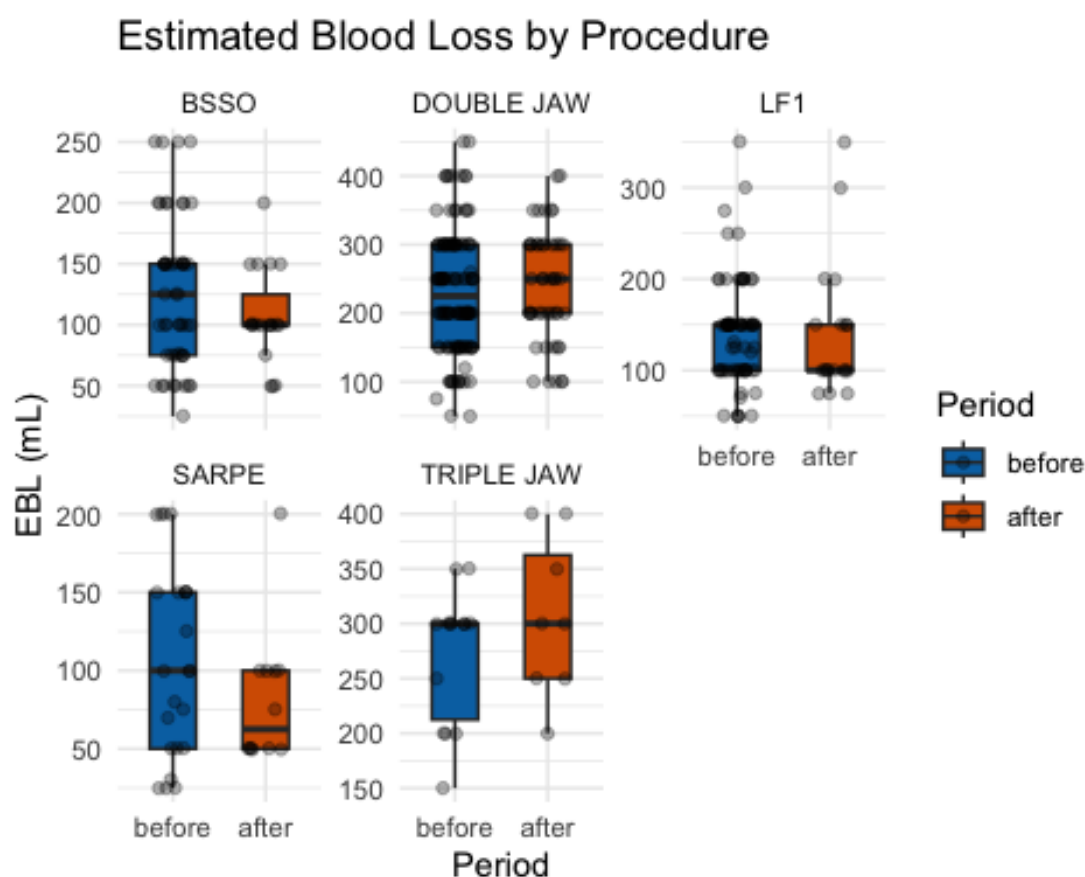


The following table shows the results of two-sample t-tests comparing post-operative IV fluid use before and after the IV fluid shortage for each surgical procedure. *ns refers to no significance.

| Procedure | Mean | | t-statistic | p-value | Lower CI | Upper CI | Significance |
|------------|--------|-------|-------------|----------|----------|----------|--------------|
| | Before | After | | | | | |
| DOUBLE JAW | 656.5 | 577.6 | 0.73 | 4.64e-01 | -133.0 | 290.7 | ns |
| LF1 | 441.1 | 275.3 | 1.42 | 1.60e-01 | -67.0 | 398.6 | ns |
| SARPE | 520.9 | 439.9 | 0.41 | 6.87e-01 | -324.8 | 486.7 | ns |

| Procedure | Mean | | t-statistic | p-value | Lower CI | Upper CI | Significance |
|------------|--------|-------|-------------|----------|----------|----------|--------------|
| | Before | After | | | | | |
| BSSO | 488.3 | 474.1 | 0.11 | 9.09e-01 | -233.3 | 261.8 | ns |
| TRIPLE JAW | 898.0 | 492.9 | 1.56 | 1.35e-01 | -137.7 | 947.9 | ns |

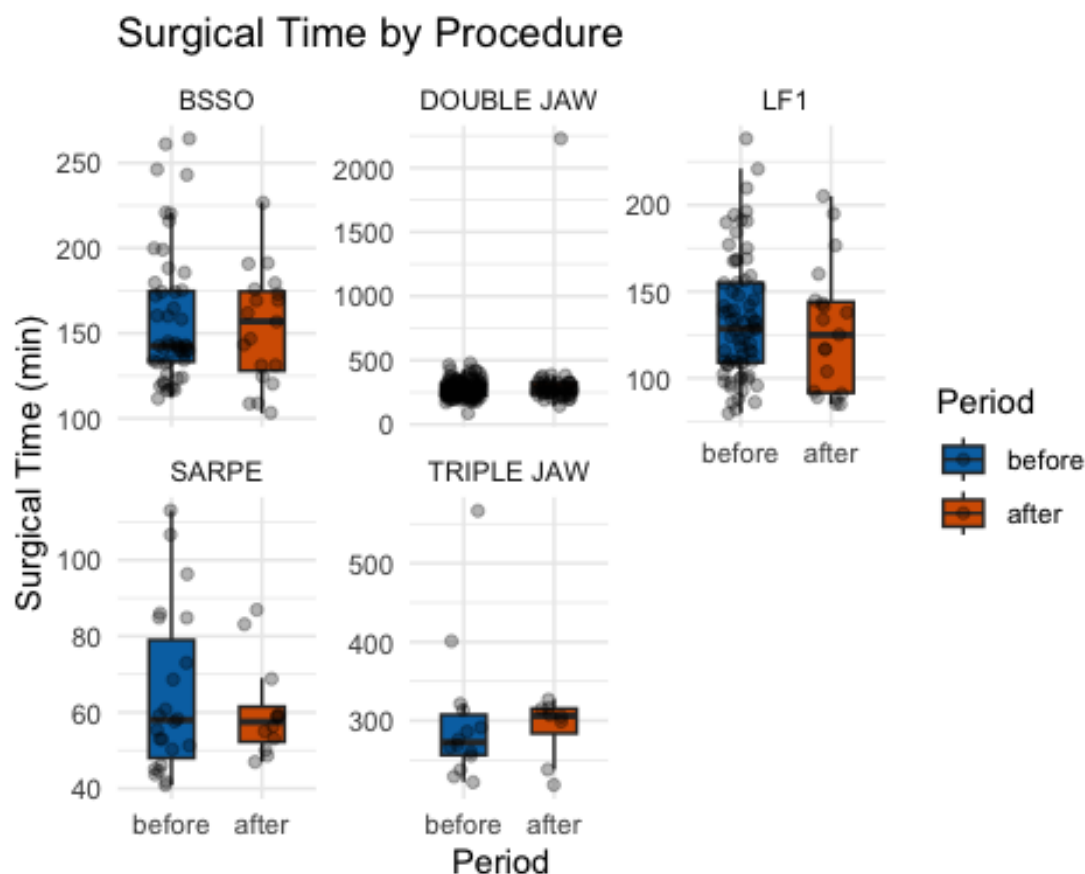
The two-sample t-tests comparing post-operative IV fluid use before and after the IV fluid shortage showed no significant differences across any surgical procedure, indicating that the shortage did not have a measurable impact on post-operative IV fluid administration for DOUBLE JAW, LF1, SARPE, BSSO, or TRIPLE JAW procedures.



The following table shows the results of two-sample t-tests comparing estimated blood loss before and after the IV fluid shortage for each surgical procedure. *ns refers to no significance.

| Procedure | Mean | | t-statistic | p-value | Lower CI | Upper CI | Significance |
|------------|--------|-------|-------------|---------|----------|----------|--------------|
| | Before | After | | | | | |
| DOUBLE JAW | 232.0 | 240.2 | -0.55 | 0.585 | -37.8 | 21.4 | ns |
| LF1 | 142.1 | 140.8 | 0.08 | 0.936 | -30.9 | 33.5 | ns |
| SARPE | 106.7 | 81.2 | 1.27 | 0.213 | -15.3 | 66.3 | ns |
| BSSO | 126.5 | 106.6 | 1.31 | 0.195 | -10.5 | 50.3 | ns |
| TRIPLE JAW | 271.4 | 306.2 | -1.20 | 0.244 | -95.4 | 25.7 | ns |

The two-sample t-tests comparing estimated blood loss before and after the IV fluid shortage revealed no significant differences for any surgical procedure, suggesting that the shortage did not meaningfully affect the estimated blood loss across DOUBLE JAW, LF1, SARPE, or BSSO cases.



The following table shows the results of two-sample t-tests comparing surgical time in minutes before and after the IV fluid shortage for each surgical procedure. *ns refers to no significance.

| Procedure | Mean | | t-statistic | p-value | Lower CI | Upper CI | Significance |
|------------|--------|-------|-------------|---------|----------|----------|--------------|
| | Before | After | | | | | |
| DOUBLE JAW | 276.1 | 316.0 | -1.41 | 0.160 | -95.7 | 15.9 | ns |
| LF1 | 134.6 | 127.9 | 0.71 | 0.479 | -11.9 | 25.1 | ns |
| SARPE | 64.1 | 60.5 | 0.54 | 0.594 | -10.1 | 17.3 | ns |
| BSSO | 158.5 | 153.3 | 0.51 | 0.613 | -15.3 | 25.8 | ns |
| TRIPLE JAW | 299.6 | 290.6 | 0.27 | 0.793 | -61.1 | 79.0 | ns |

The two-sample t-tests comparing the surgical time based on procedure before and after the IV fluid shortage revealed no significant differences for any surgical procedure, suggesting that the shortage did not meaningfully affect surgical time across DOUBLE JAW, LF1, SARPE, or BSSO cases.

Conclusion

Our analysis revealed that despite the significant disruption caused by Hurricane Helene and the resulting nationwide IV fluid shortage, most post-operative outcomes across orthognathic surgical procedures remained stable, with no significant differences observed in estimated blood loss, post-operative IV fluid use, or length of hospital stay for most procedures.