Surgery in the Pyrocene: Association of Air Pollution And Major Post-Operative Complications

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1U4U Innovation Funding

Funded Project Amount: $30,000

Abstract

Background: While exposure to fine particulate matter air pollution (PM2.5), a component of Wildfire Smoke, is known to cause adverse health effects, its impact on postoperative outcomes in US adults remains understudied. Perioperative exposure to PM2.5 may induce inflammation that interacts insidiously with the surgical stress response, leading to higher postoperative complications.

Methods: We conducted a single center, retrospective cohort study using data from 49,615 surgical patients living along Utah's Wasatch Front and who underwent elective surgical procedures at a single academic medical center from 2016-2018. Patients' addresses were geocoded and linked to daily Census-tract level PM2.5 estimates. We hypothesized that elevated PM2.5 concentrations in the week prior to surgery would be associated with an increase in a bundle of major postoperative complications. A hierarchical Bayesians regression model was fit adjusting for age, sex, season, neighborhood disadvantage, and the Elixhauser index of comorbidities.

Results: Postoperative complications increased in a dose-dependent manner with higher concentrations of PM2.5 exposure, with a relative increase of 8% in the odds of complications (OR=1.082) for every 10ug/m3 increase in the highest single-day 24-hr PM2.5 exposure during the 7 days prior to surgery. For a 30 fold increase in PM2.5 (1 ug/m3 to 30ug/m3) the odds of complication rose to over 27% (95%CI: 4%-55%). The association persisted after controlling for comorbidities and confounders; our inferences were robust to modeling choices and sensitivity analysis.

Conclusions: In this large Utah cohort, exposure to elevated PM2.5 concentrations in the week before surgery was associated with a dose-dependent increase in postoperative complications, suggesting a potential impact of air pollution on surgical outcomes. These findings merit replication in larger datasets to identify populations at risk and define the interaction and impact of different pollutants. PM2.5 exposure is a potential perioperative risk factor and, given the unmitigated air pollution in urban areas, a global health concern.

Introduction

- Exposure to air pollution is associated with adverse health effects(Pearson, 2011; Atkinson, 2014; Farhadi, 2020; Shah, 2015; Fu, 2018), but its impact on postoperative outcomes is not well studied as a knowledge gap remains regarding the impact of **individual perioperative patient air pollution exposure with small particles (IPAPE).**
- Described in less than 2 dozen studies(Kovtun, 2021; Huang, 2023) IPAPE may augment physiological mechanisms inherent in the surgical stress response and increase perioperative morbidity and mortality(Gutierrez, 2011).
- If true, this could drive targeted perioperative mitigation (e.g. re-scheduling surgery for at-risk patients or improved home ventilation) and would have significant environmental policy implications.
- Utilizing the natural weather events of northern Utah, USA, where poor air quality is cleared by frequent weather events at random, we aimed to determine if preoperative exposure to fine particulate matter (PM2.5), a component of wildfire smoke, is associated with increased postoperative complications.

Consort Flow Diagram

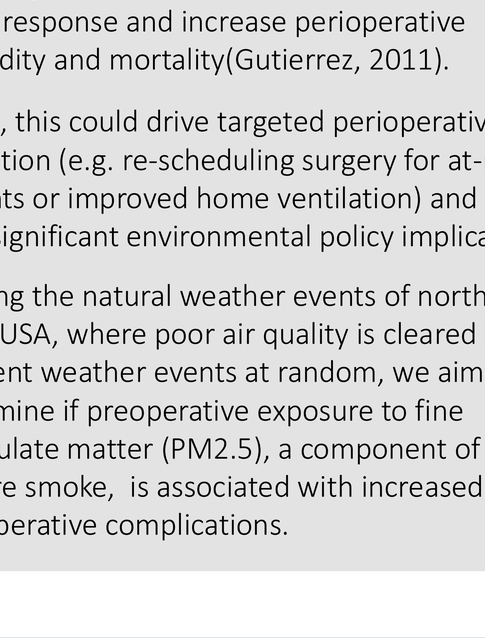

Figure 1 details our initial cohort downloaded from Data Direct from MPOG.org and the process of exclusion criteria applied to generate our final cohort. Of note, the greatest number of patients eliminated was when excluding those who lived outside of the Wasatch Front study area.

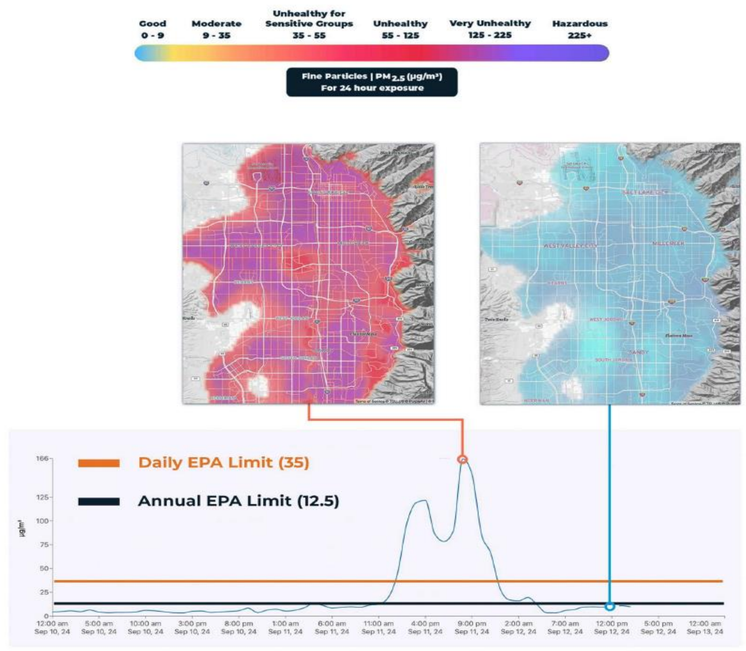

Figure 2 illustrates the rapidly changing pollution levels along the "Wasatch Front" mountain range in Salt Lake City, UT. The unique mountain geography of the "Wasatch Front," along with five oil refineries, multiple industrial facilities, 2.2 million people, the intersection of two major interstate highways, and a national train depot, work together to produce the increased occurrence of extreme pollution events in the region, which dramatically impact ambient $PM_{2.5}$ concentrations[32,58,59]. This results in inversion conditions during the winter, with warm air aloft the valley trapping cold air and pollutants in the densely populated valley below. Similarly, in the summer when wildfires throughout the American West dominate pollution exposures, the geological bowl produced by the intersection of multiple mountain ranges that comprise the Wasatch Front act as a shield that accumulates wildfire smoke in the metropolitan region. In both instances, low pressure systems tend to rapidly clear the area of pollutants, at random. As a result, patients are quasi-randomly exposed to high or low pollution levels, while their surgery scheduling is disregarding this exposure, leading to a natural experiment. The left map illustrates high observed pollution levels (red/purple for unhealthy high pm 2.5 levels) due to a recent wildfire event on September 11-12, 2024 while the right map demonstrates how a change in weather patterns cleared the air, leading to suddenly much lower pollution exposures (blue). The graph demonstrates this timeline of rapidly changing 2.5 small particle pollution levels, with markers for the dates of the maps.

Methodology

- We conducted a retrospective cohort study using data from 49,615 surgical patients from the University of Utah, all of whom resided along Utah's Wasatch Front from 2016-2018.
- Individual patient addresses were geocoded and linked to daily the maximum value PM2.5 estimates at the Census Tract level over 7 days preoperatively from a large scale fused air quality wildfire model(Reid, 2021).
- We constructed multivariate Bayesian hierarchical models to test the association between max 7-day PM2.5 exposure as a bivariate at exposure threshold of 35 ug/m3 and our primary outcome, a composite of major complications (stroke, myocardial infarction, acute kidney injury, surgical site infection)
- Models adjusted for age, sex, year, season (fire/cars/other), county, Neighborhood Depirvation, and Elixhauser comorbidity index (van Walraven, 2009; Austin, 2015)

Conclusion

- In this large Utah cohort, exposure to elevated PM2.5 in the 3 weeks prior to surgery was associated with markedly increased postoperative complications.
- While preliminary, our findings underscore the need to study this question in more diverse regions and populations.
- Determining patient-level preoperative pollution exposure could identify those at higher risk of complications.
- Further, we may be able to mitigate risks with personal protective equipment or advanced air filtration at home.
- Our findings have international importance as air pollution and PM2.5 are still considered potent public health threats globally, and levels of >30 ug/m3 are commonly exceeded
- This work may inform public policy and econometric models on the health effects of air pollution.

Results

- The postoperative complication rate increased with higher levels of PM2.5 in the model, even after adjusting for comorbidities, with OR 1.082 for every 10ug/m3 of increase in PM2.5
- PM2.5 levels of >30 ug/m3 were associated with an OR of 1.27 (95% CI 1.04 – 1.55)
- This translates to a 27% increased risk of complications on days where PM2.5 >30 ug/m3
- Elixhauser Comorbidity Index was seen to increase risk of surgical complications, indicating proper model calibration

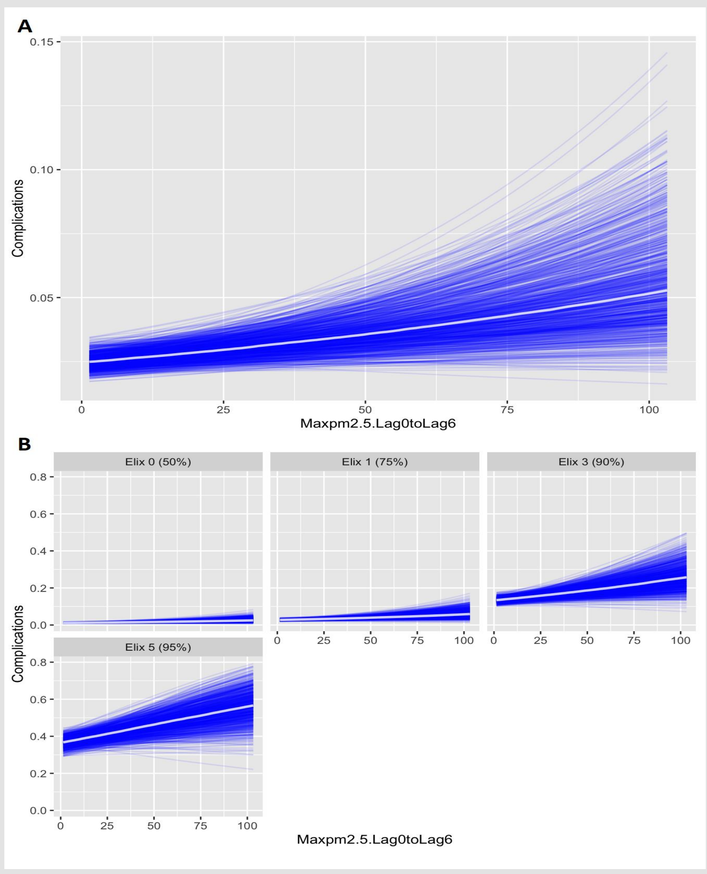

Figure 3: Maximum PM2.5 in the 7 days pre-operatively (Lag0-Lag6) vs. Complication Rate. Panel A (top) details Complications Rate vs. Maximum PM2.5 of the 7-day lag period, while Panel B (bottom) details the same broken down by Elixhuaser Comorbidity Index. Complication rate is shown as absolute value, so here 0.04 = 4% complication rate. The PM2.5 values are the maximum observed in the 7-day preop window, in ug/m^3, Lag 0 is day of surgery. In Panel B as noted, the overall complication rate for those with higher Elixhauser comorbidity index is higher at baseline, but rose more quickly with elevations in PM2.5. This response to PM2.5 continued to increase in magnitude as Elixhauser index increased. Note that the effect of PM2.5 was greater among this with Elixhauser of 5, but that the baseline complication rate was also higher.

References

1. Pearson JF, Bachireddy C, Shyamprasad S, Goldfine AB, Brownstein JS. Association between fine particulate matter and diabetes prevalence in the U.S. Diabetes Care. Oct 2010;33(10):2196-201.doi:10.2337/dc10-0698
2. Atkinson RW, Kang S, Anderson HR, Mills IC, Walton HA. Epidemiological time series studies ofPM2.5 and daily mortality and hospital admissions: a systematic review and meta-analysis. Thorax. Jul2014;69(7):660-5. doi:10.1136/thoraxjnl-2013-204492
3. Farhadi Z, Abulghasem Gorgi H, Shabaninejad H, Aghajani Delavar M, Torani S. Association between PM(2.5) and risk of hospitalization for myocardial infarction: a systematic review and ameta-analysis. BMC Public Health. Mar12 2020;20(1):314. doi:10.1186/s12889-020-8262-3
4. Shah AS,Lee KK, McAllister DA, et al. Short term exposure to air pollution and stroke: systematic review andmeta-analysis. BMJ. Mar 24 2015;350:h1295. doi:10.1136/bmj.h1295
5. Fu P, Guo X, Cheung FMH, Yung KKL. The association between PM(2.5) exposure and neurological disorders:A systematic review and meta-analysis. Sci Total Environ. Mar 10 2019;655:1240-1248.doi:10.1016/j.scitotenv.2018.11.218
6. Kovtun R, Ha L, Mendoza D, Pearson J. Influence of Air Pollution on Perioperative Outcomes &Potential for Big Data Driven Discoveries. LIPPINCOTT WILLIAMS & WILKINS TWO COMMERCE SQ,2001 MARKET ST, PHILADELPHIA; 2021:49-51.
7. Huang J, Xing J, Zou EY. (Re) scheduling pollution exposure: The case of surgery schedules. Journal of Public Economics. 2023;219:104825.
8. Gutierrez T, Hornigold R, Pearce A. The systemic response to surgery. Surgery (Oxford).2011;29(2):93-96.
9. Reid, Colleen E., et al. "Daily PM2. 5 concentration estimates by county, ZIP code, and census tract in 11 western states 2008-2018." Scientific data 8.1 (2021): 112.
10. van Walraven C, Austin PC, Jennings A, Quan H, Forster AJ. A modification of the Elixhauser comorbidity measures into a point system for hospital death using administrative data. Med Care. Jun 2009;47(6):626-33. doi:10.1097/MLR.0b013e31819432e5
11. Austin SR, Wong YN, Uzzo RG, Beck JR, Egleston BL. Why Summary Comorbidity Measures Such As the Charlson Comorbidity Index and Elixhauser Score Work. Med Care. Sep 2015;53(9):e65-72.doi:10.1097/MLR.0b013e318297429c

Acknowledgements

Our team would like to acknowledge the hard work and dedication of our co-investigator and research assistants including but not limited to: Cameron Jacobson, Nathan Pace, Michael Andreae, Kai Wilmot and Jiuying Han. We also gratefully acknowledge the ongoing support of the Department of Anesthesiology and the Global Change and Sustainability Center.

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